INSTITUTION

OF

MECHANICAL ENGINEERS.

PROCEEDINGS.

1859.

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1859.

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1859.

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LIST OF MEMBERS,

WITH YEAR OF ELECTION.

1859.

LIFE MEMBERS.

1853. Maudslay, Henry, 4 Cheltenham Place, Lambeth, London, S.
1848. Penn, John, The Cedars, Lee, Kent, S.E.
1847. Stephenson, Robert, M.P., 24 Great George Street, Westminster, S.W.

MEMBERS.

1859. Adams, William, Locomotive Superintendent, North London Railway, Bow, London, E.
1848. Adams, William Alexander, Midland Works, Birmingham.
1859. Adamson, Daniel, Newton Moor Iron Works, Hyde, near Manchester.
1851. Addison, John, 6 Delahay Street, Westminster, S.W.
1853. Adkins, Francis, Heath Lead Works, near Birmingham.
1858. Albaret, Auguste, Locomotive Engineer, Portuguese Railways, Lisbon.
1847. Allan, Alexander, Locomotive Superintendent, Scottish Central Railway, Perth.
1856. Allen, Edward Ellis, 37 Brompton Row, London, S.W.
1856. Allen, James, Cambridge Street Works, Manchester.
1859. Alton, George, Midland Railway Works, Derby.
1856. Anderson, John, Assistant Superintendent, Royal Gun Factories, Royal Arsenal, Woolwich, S.E.
1856. Anderson, William, Messrs. Courtney Stephens and Co., Blackall Place Iron Works, Dublin.
1858. Appleby, Charles Edward, Mining Engineer, 90 Greenhill, Derby.
1859. Armitage, William James, Farnley Iron Works, Leeds.
1857. Armstrong, Joseph, Great Western Railway, Locomotive Department, Wolverhampton.
1858. Armstrong, Sir William George, Elswick, Newcastle-on-Tyne.
1857. Ashbury, James Lloyd, Openshaw Works, near Manchester.
1848. Ashbury, John, Openshaw Works, near Manchester.
1858. Atkinson, Charles, Fitzalan Steel Works, Sheffield.

1848. Bagnall, William, Gold's Hill Iron Works, Westbromwich.
1848. Baker, William, London and North Western Railway, Euston Station, London, N.W.
1847. Barwell, William Harrison, Eagle Foundry, Northampton.
1859. Bastow, Samuel, Cliff House Iron Works, West Hartlepool.
1859. Beacock, Robert, Victoria Foundry, Leeds.
1848. Beattie, Joseph, Locomotive Superintendent, London and South Western Railway, Nine Elms, London, S.
1859. Beck, Edward, Jun., Messrs. Neild and Co., Dallam Iron Works, Warrington.
1858. Bell, Isaac Lowthian, Clarence Felling and Wylam Iron Works, Newcastle-on-Tyne.
1857. Bellhouse, Edward Taylor, Eagle Foundry, Hunt Street, Oxford Street, Manchester.
1854. Bennett, Peter Duckworth, Spon Lane Iron Works, Westbromwich.
1847. Beyer, Charles, Messrs. Beyer Peacock and Co., Gorton, near Manchester.
1847. Birley, Henry, Haigh Foundry, near Wigan.
1856. Blackburn, Isaac, 35 Parliament Street, Westminster, S.W.
1851. Blackwell, Samuel Holden, Russell's Hall Iron Works, near Dudley.
1858. Bouch, William, Shildon Engine Works, Darlington.
1847. Bovill, George Hinton, Durnsford Lodge, near Wandsworth, Surrey, S.W.
1858. Bower, John Wilkes, Messrs. Sharp Stewart and Co., Atlas Works, Manchester.
1854. Bragge, William, Atlas Steel Works, Sheffield.
1854. Bramwell, Frederick Joseph, 35A Great George Street, Westminster, S.W.
1856. Bray, Edwin, New Dock Iron Works, Leeds.
1848. Broad, Robert, Horseley Iron Works, near Tipton.
1852. Brogden, Henry, Ulverstone, Cumberland.
1847. Brown, James, Jun., Messrs. James Watt and Co., Soho Foundry, near Birmingham.
1850. Brown, John, Atlas Steel Works, Sheffield.
1855. Brown, John, Mining Engineer, Barnsley, Yorkshire.
1856. Brown, John, Mining Engineer, Bank Top, Darlington.
1853. Brown, Ralph, Patent Shaft Works, Wednesbury.
1859. Buckton, Joshua, Well House Foundry, Leeds.
1858. Burlinson, William D., Millfield Engine Works, Sunderland.
1858. Burn, Henry, Danube and Black Sea Railway, Kustendjie, near Varna.
1856. Butler, Ambrose Edmund, Kirkstall Forge, Leeds.
1859. Butler, John, Old Foundry, Stanningley, near Leeds.
1859. Butler, John Octavius, Kirkstall Forge, Leeds.

1857. Cabry, Joseph, Midland Great Western Railway, Dublin.
1847. Cabry, Thomas, North Eastern Railway, York.
1847. Cammell, Charles, Cyclops Steel Works, Sheffield.
1856. Carrett, William Elliott, Sun Foundry, Leeds.
1858. Carson, James I., Locomotive Superintendent, West Hartlepool Harbour and Railway, Stockton-on-Tees.
1849. Chamberlain, Humphrey, Clerkenleap, Kempsey, near Worcester.
1852. Chellingworth, Thomas T., Sydenham Works, Westbromwich.
1857. Chrimes, Richard, Messrs. Guest and Chrimes, Brass Works, Rotherham.
1854. Clark, Daniel Kinnear, 11 Adam Street, Adelphi, London, W.C.
1859. Clark, George, Monkwearmouth Engine Works, Sunderland.
1859. Clay, William, Mersey Steel and Iron Works, Sefton Street, Liverpool.
1847. Clift, John Edward, Durnford Place, Coventry Road, Birmingham.
1847. Cochrane, Alexander Brodie, Woodside Iron Works, near Dudley.
1858. Cochrane, Charles, Ormsby Iron Works, Middlesborough.
1854. Cochrane, John, Woodside Iron Works, near Dudley.
1847. Coke, Richard George, Ankerbold, near Chesterfield.
1853. Cooper, Samuel Thomas, Leeds Iron Works, Leeds.
1848. Corry, Edward, 8 New Broad Street, London, E.C.
1857. Cortazzi, Francis James, Great Northern Railway, Locomotive Department, Peterborough.
1849. Cowper, Charles, 20 Southampton Buildings, Chancery Lane, London, W.C.
1847. Cowper, Edward Alfred, 35A Great George Street, Westminster, S.W.
1853. Craig, William Grindley, Perry Hill, Sydenham, Kent, S.E.
1847. Crampton, Thomas Russell, 15 Buckingham Street, Adelphi, London, W.C.
1858. Crawhall, Joseph, St. Ann's Wire and Hemp Rope Works, Newcastle-on-Tyne.
1857. Criswick, Theophilus, Plymouth Iron Works, Merthyr Tydvil.
1858. Cubitt, Charles, Westminster New Bridge Works, South Lambeth, London, S.

1849. Dawes, George, Milton and Elsecar Iron Works, near Barnsley, Yorkshire.
1857. Deane, John Horridge, 7 Falkner Square, Liverpool.
1857. De Bergue, Charles, Strangeways Iron Works, Manchester.
1858. Dees, James, Whitehaven.
1858. Dempsey, William, 26 Great George Street, Westminster, S.W.
1859. Dixon, John, Railway Foundry, Bradford, Yorkshire.
1854. Dodds, Thomas W., Holmes Engine Works, Rotherham.
1857. Douglas, George, Resident Engineer, Birkenhead Lancashire and Cheshire Junction Railway, Birkenhead.
1857. Dove, George, Woodbank Iron Works, Carlisle.

1856. Dudgeon, John, 151 Fenchurch Street, London, E.C.
1856. Dudgeon, William, 151 Fenchurch Street, London, E.C.
1857. Dunlop, John Macmillan, Marlborough Street, Oxford Street, Manchester.
1854. Dunn, Thomas, Windsor Bridge Iron Works, Manchester.

1859. Eassie, Peter Boyd, Saw Mills, High Orchard, Gloucester.
1858. Easton, Edward, Grove Works, Southwark, London, S.E.
1856. Eastwood, James, Railway Iron Works, Derby.
1859. Egleston, Thomas, Jun., 3 Rue des Beaux Arts, Paris.
1859. Elliot, George, Houghton-le-Spring, near Fence Houses.
1853. England, George, Hatcham Iron Works, New Cross, Surrey, S.E.
1857. Evans, John Campbell, Morden Iron Works, East Greenwich, S.E.
1848. Everitt, George Allen, Kingston Metal Works, Adderley Street, Birmingham.

1857. Fairlie, Robert Francis, 224 Gresham House, Old Broad Street, London, E.C.
1856. Fay, Charles, Lancashire and Yorkshire Railway, Carriage Department, Manchester.
1847. Fenton, James, Low Moor Iron Works, near Bradford, Yorkshire.
1854. Fernie, John, Midland Railway, Locomotive Department, Derby.
1847. Fletcher, Edward, Locomotive Superintendent, North Eastern Railway, Gateshead.
1858. Fletcher, Henry Allason, Lowca Engine Works, Whitehaven.
1857. Fletcher, James, Messrs. W. Collier and Co., 2 Greengate, Salford, Manchester.
1859. Fogg, Robert, 17 Park Street, Westminster, S.W.
1849. Forsyth, John C., North Staffordshire Railway, Stoke-upon-Trent.
1847. Fothergill, Benjamin, Museum of Patents, Kensington, London, W.
1847. Fowler, John, 2 Queen Square Place, Westminster, S.W.
1857. Fowler, John, Jun., 28 Cornhill, London, E.C.
1859. Fowler, William, Sheep Bridge Iron Works, near Chesterfield.
1847. Fox, Sir Charles, 8 New Street, Spring Gardens, London, S.W.
1859. Fraser, John, Resident Engineer, Leeds Bradford and Halifax Junction Railway, Leeds.
1853. Fraser, Joseph Boyes, Alma Place, Kenilworth.
1856. Freeman, Joseph, 22 Cannon Street, London, E.C.
1852. Froude, William, Elmsleigh, Paignton, Torquay.

1847. Garland, William S., Messrs. James Watt and Co., Soho Foundry, near Birmingham.
1848. Gibbons, Benjamin, Hill Hampton House, near Stourport.
1856. Gilkes, Edgar, Tees Engine Works, Middlesborough.
1854. Goode, Benjamin W., St. Paul's Square, Birmingham.

*1847. Goodfellow, Benjamin, Hyde Iron Works, Hyde, near Manchester.
1848. Green, Charles, Tube Works, Leek Street, Birmingham.
1858. Greenwood, Thomas, Albion Foundry, Leeds.
1857. Gregory, John, Engineer, Portuguese National Railway South of Tagus, Barriero, near Lisbon.

1857. Hall, William, Bloomfield Iron Works, Tipton.
1858. Harding, John, Beeston Manor Iron Works, Leeds.
1859. Harman, Henry William, Steam Boiler Association, 41 Corporation Street, Manchester.
1856. Harrison, George, Canada Works, Birkenhead.
1858. Harrison, Thomas Elliot, North Eastern Railway, Newcastle-on-Tyne.
1848. Hartree, William, Messrs. John Penn and Co., Marine Engineers, Greenwich, S.E.
1859. Harvey, William Beauchamp Bagnal, Engineer, H. M. Mint, Calcutta; Bagnal Villa, Gresham Road, Brixton, London, S.
1858. Haswell, John A., North Eastern Railway, Locomotive Department, Gateshead.
1857. Haughton, S. Wilfred, Locomotive Superintendent, Dublin and Wicklow Railway, Dublin.
1856. Hawksley, Thomas, 30 Great George Street, Westminster, S.W.
1848. Hawthorn, Robert, Forth Banks, Newcastle-on-Tyne.
1848. Hawthorn, William, Forth Banks, Newcastle-on-Tyne.
1859. Head, Jeremiah, Messrs. Kitson and Co., Airedale Foundry, Leeds.
1858. Head, Thomas Howard, Teesdale Iron Works, Stockton-on-Tees.
1853. Headly, James Ind, Eagle Works, Cambridge.
1857. Healey, Edward Charles, 163 Strand, London, W.C.
1858. Hedley, John, Resident Engineer, South Hetton Colliery, near Fence Houses.
1850. Henson, Henry H., 38 Parliament Street, Westminster, S.W.
1848. Hewitson, William Watson, Messrs. Kitson and Co., Airedale Foundry, Leeds.
1859. Hobbs, Alfred Charles, Arlington Street, New North Road, London, N.
1858. Hodgson, Robert, North Eastern Railway, Newcastle-on-Tyne.
1852. Holcroft, James, Shut End, Brierley Hill, Worcestershire.
1848. Homersham, Samuel Collett, 19 Buckingham Street, Adelphi, London, W.C.
1856. Hopkinson, John, Messrs. Wren and Hopkinson, Altrincham Street, Manchester.
1858. Hopper, George, Houghton-le-Spring Iron Works, near Fence Houses.
1851. Horton, Joshua, Etna Works, Smethwick, near Birmingham.
1858. Horsley, William, Jun., Hartley Engine Works, Seaton Sluice, near North Shields.
1858. Hosking, John, Gateshead Iron Works, Gateshead.

1847. Howell, Joseph, Hawarden Iron Works, Holywell, Flintshire.
1857. Humber, William, Pancras Chambers, Pancras Lane, Bucklersbury, London, E.C.
1859. Hunt, James P., Corngreaves Iron Works, Corngreaves, near Birmingham.
1856. Hunt, Thomas, London and North Western Railway, Locomotive Department, Crewe.

1850. Ikin, Jonathan Dickson, 2 Cannon Row, Westminster, S.W.
1857. Inshaw, John, Engine Works, Morville Street, Birmingham.

1859. Jackson, Matthew Murray, Messrs. Escher Wyss and Co., Engine Works, Zurich.
1847. Jackson, Peter Rothwell, Salford Rolling Mills, Manchester.
1858. Jaffrey, George William, Hartlepool Iron Works, Hartlepool.
1856. James, Jabez, 28A Broadwall, Stamford Street, Lambeth, London, S.
1855. Jeffcock, Parkin, Mining Engineer, 3 Stuart Terrace, Greenhill, Derby.
1856. Jeffreys, Edward, Locomotive Superintendent, Shrewsbury and Hereford Railway, Shrewsbury.
1857. Jenkins, William, Locomotive Superintendent, Lancashire and Yorkshire Railway, Miles Platting, Manchester.
1854. Jobson, John, Derwent Foundry, Derby.
1847. Jobson, Robert, Dudley.
1847. Johnson, James, Great Northern Railway, Locomotive Department, Doncaster.
1848. Johnson, Richard William, The Laurels, Hagley Road, Birmingham.
1849. Johnson, William, 166 Buchanan Street, Glasgow.
1855. Johnson, William Beckett, St. George's Iron Works, Hulme, Manchester.
1847. Jones, Edward, Old Park Iron Works, Wednesbury.
1857. Jones, John Hodgson, 26 Great George Street, Westminster, S.W.
1853. Joy, David, Messrs. C. De Bergue and Co., Strangeways Iron Works, Manchester.

1857. Kay, James Clarkson, Phœnix Foundry, Bury, Lancashire.
1857. Kendall, William, Locomotive Superintendent, Blyth and Tyne Railway, Percy Main, near North Shields.
1847. Kennedy, James, Cressington Park, Aigburth, Liverpool.
1857. Kennedy, Lieut.-Col. John Pitt, R.E., Engineer, Bombay Baroda & Central Indian Railway; 10 Liverpool Street, New Broad Street, London, E.C.
1848. Kinmond, William L., Hamilton Steam Engine and Forge Works, Hamilton, Canada West.
1848. Kirkham, John, 109 Euston Road, London, N.W.
1847. Kirtley, Matthew, Locomotive Superintendent, Midland Railway, Derby.

1859. Kitson, Frederick William, Monkbridge Iron Works, Leeds.
1848. Kitson, James, Airedale Foundry, Leeds.
1859. Kitson, James, Jun., Monkbridge Iron Works, Leeds.

1858. Laurent, François, Inspecting Engineer, Rome and Civita Vecchia Railway.
1857. Laybourn, John, Isca Foundry, Newport, Monmouthshire.
1856. Laybourn, Richard, Locomotive Superintendent, Monmouthshire Railway and Canal Company, Newport, Monmouthshire.
1857. Lees, John, Park Bridge Iron Works, Ashton-under-Lyne.
1857. Lees, Sylvester, Locomotive Superintendent, East Lancashire Railway, Bury, Lancashire.
1858. Leslie, Andrew, Iron Ship Building Yard, Hebburn Quay, Gateshead.
1856. Levick, Frederick, Cwm-Celyn Blaina and Coalbrook Vale Iron Works, near Newport, Monmouthshire.
1856. Linn, Alexander Grainger, 121 Upper Parliament Street, Liverpool.
1857. Little, Charles, Midland Railway, Locomotive Department, Derby.
1854. Lloyd, George Braithwaite, Messrs. Lloyds, High Street, Birmingham.
1847. Lloyd, Sampson, Old Park Iron Works, Wednesbury.
1852. Lloyd, Samuel, Jun., Old Park Iron Works, Wednesbury.
1856. Longridge, Robert Bewick, Steam Boiler Assurance Company, New Brown Street, Market Street, Manchester.
1859. Lord, Thomas Wilks, 32 Boar Lane, Leeds.
1854. Lynde, James Gascoigne, Town Hall, Manchester.

1856. Mackay, John, Drogheda Iron Works, Drogheda.
1859. Manning, John, Boyne Engine Works, Hunslet, Leeds.
1857. March, George, Union Foundry, Leeds.
1856. Markham, Charles, Midland Railway, Derby.
1848. Marshall, Edwin, Britannia Carriage Works, Birmingham.
1859. Marshall, William Ebenezer, Sun Foundry, Leeds.
1847. Marshall, William Prime, 81 Newhall Street, Birmingham.
1859. Marten, Edward Bindon, Stourbridge Water Works, Stourbridge.
1853. Marten, Henry, Parkfield Iron Works, near Wolverhampton.
1857. Martindale, Capt. Ben Hay, R.E., Superintendent of Railway and Civil Works, Sydney, New South Wales.
1854. Martineau, Francis Edgar, Globe Works, Cliveland Street, Birmingham.
1857. Masselin, Armand, Spon Lane Glass Works, near Westbromwich.
1853. Mathews, William, Corbyn's Hall Iron Works, near Dudley.
1848. Matthew, John, Messrs. John Penn & Co., Marine Engineers, Greenwich, S.E.
1847. Matthews, William Anthony, Sheaf Works, Sheffield.
1859. May, Charles, 3 Great George Street, Westminster, S.W.
1857. May, Walter, Suffolk Works, Berkley Street, Birmingham.

1859. Maylor, William, East Indian Iron Company, Beypoor: (or care of E. J. Burgess, 8 Austin Friars, London, E.C.)
1847. McClean, John Robinson, 17 Great George Street, Westminster, S.W.
1847. McConnell, James Edward, Locomotive Superintendent, London and North Western Railway, Wolverton.
1859. McKenzie, John, Locomotive Superintendent, Oxford Worcester and Wolverhampton Railway, Worcester.
1858. Meik, Thomas, Engineer to the River Wear Commissioners, Sunderland.
1857. Menelaus, William, Dowlais Iron Works, Merthyr Tydvil.
1857. Metford, William Ellis, Flook House, Taunton.
1847. Middleton, William, Vulcan Iron Foundry, Summer Lane, Birmingham.
1853. Miller, George Mackey, Great Southern and Western Railway, Dublin.
1847. Miller, Joseph, Mill Ellers, Dalston, near Carlisle.
1856. Mitchell, Charles, Iron Ship Building Yard, Low Walker, Newcastle-on-Tyne.
1858. Mitchell, James, Melrose Cottage, Plumstead Common, near Woolwich, S.E.
1859. Moor, William, Engineer, Hetton Colliery, Hetton, near Fence Houses.
1849. Morrison, Robert, Ouseburn Engine Works, Newcastle-on-Tyne.
1858. Mountain, Charles George, Suffolk Works, Berkley Street, Birmingham.
1857. Mowbray, Frederick William, Queen's Gate, Bradford, Yorkshire.
1857. Muntz, George Frederick, French Walls, near Birmingham.
1856. Muntz, George Henri Marc, 3 Lansdowne Terrace, Handsworth, near Birmingham.
1859. Murphy, James, Railway Works, Newport, Monmouthshire.
1858. Murray, Thomas H., Engine Works, Chester-le-Street, near Fence Houses.

1848. Napier, John, Vulcan Foundry, Glasgow.
1856. Napier, Robert, Vulcan Foundry, Glasgow.
1858. Naylor, William, Great Indian Peninsula Railway, 3 New Broad Street, London, E.C.
1856. Newall, James, East Lancashire Railway, Carriage Department, Bury, Lancashire.
1858. Nichol, Peter Dale, East Indian Railway, Locomotive Department, Howrah, Calcutta: (or care of Anthony Nichol, Quay Side, Newcastle-on-Tyne.)
1851. Nixon, Charles, 3 Victoria Street, Westminster, S.W.
1850. Norris, Richard Stuart, London and North Western Railway, Engineer's Office, Liverpool.

1847. Owen, William, Messrs. Sandford and Owen, Phœnix Works, Rotherham.

1859. Paquin, Jean François, Locomotive Superintendent, Madrid Saragossa and Alicante Railways, Madrid.
1858. Parkinson, John, Victoria Brass and Copper Works, Bury, Lancashire.

1853. Payne, Edward J., 1 Bennett's Hill, Birmingham.
1847. Peacock, Richard, Messrs. Beyer Peacock & Co., Gorton, near Manchester.
1848. Pearson, John, Liver Iron Works, Boundary Street, Liverpool.
1859. Peet, Henry, Lancaster and Carlisle Railway, Locomotive Department, Carlisle.
1856. Perring, John Shae, Resident Engineer, East Lancashire Railway, Bury, Lancashire.
1856. Piggott, George, Birmingham Heath Boiler Works, Birmingham.
1854. Pilkington, Richard, Jun., St. Helen's Iron Works, St. Helen's.
1859. Pim, Jonathan, Locomotive Superintendent, Waterford and Limerick Railway, Limerick.
1859. Pitts, Joseph, Old Foundry, Stanningley, near Leeds.
1852. Plant, Reuben, Pensnett Collieries, Brierley Hill, Worcestershire.
1859. Platt, John, Hartford Iron Works, Oldham.
1856. Pollard, John, Midland Junction Foundry, Leeds.
1852. Porter, John Henderson, Iron Roofing Works, Gas Street, Birmingham.
1856. Preston, Francis, Ancoats Bridge Works, Ardwick, Manchester.
1848. Preston, Robert Berthon, 10 Abercrombie Square, Liverpool.
1855. Prideaux, Thomas Symes, 32 Charing Cross, London, S.W.

1847. Ramsbottom, John, Locomotive Superintendent, London and North Western Railway, Crewe.
1859. Rennie, George Banks, 21 Whitehall Place, Westminster, S.W.
1856. Richards, Josiah, Ebbw Vale Iron Works, near Tredegar.
1858. Richardson, Thomas, Hartlepool Iron Works, Hartlepool.
1859. Richardson, William, Hartford Iron Works, Oldham.
1848. Robertson, Henry, Shrewsbury and Chester Railway, Shrewsbury.
1859. Robinson, John, Messrs. Sharp Stewart and Co., Atlas Works, Manchester.
1858. Robson, Jonathan, Blackwall Engine and Iron Ship Building Works, Gateshead.
1852. Rofe, Henry, Engineer, Birmingham Water Works, Paradise Street, Birmingham.
1851. Rogers, Ebenezer, Abercarn, near Newport, Monmouthshire.
1851. Rolinson, Thomas, Wellington Road, Dudley.
1853. Ronayne, Joseph P., Harbour Hill, Queenstown, Cork.
1853. Ross, John, Messrs. Brown Marshalls and Co., Britannia Carriage Works, Birmingham.
1856. Rouse, Frederick, Great Northern Railway, Locomotive Department, Leeds.
1857. Routledge, William, New Bridge Foundry, Salford, Manchester.
1856. Russel, Robert, Clooney Terrace, Waterside, Londonderry.
1847. Russell, John Scott, 20 Great George Street, Westminster, S.W.
1859. Ryder, John Northcote, Change Alley Chambers, 24 Cornhill, London, E.C.

1859. Sacré, Charles, Locomotive Superintendent, Manchester Sheffield and Lincolnshire Railway, Gorton, near Manchester.

1859. Salt, George, Saltaire, near Bradford, Yorkshire.

1848. Samuel, James, 26 Great George Street, Westminster, S.W.

1857. Samuelson, Alexander, Scott Street Foundry, Hull.

1857. Samuelson, Martin, Scott Street Foundry, Hull.

1858. Scott, Joseph, Messrs. R. & W. Hawthorn, Forth Banks, Newcastle-on-Tyne.

1848. Scott, Michael, 26 Great George Street, Westminster, S.W.

1857. Selby, George Thomas, Smethwick Tube Works, Birmingham.

1850. Shanks, Andrew, 6 Robert Street, Adelphi, London, W.C.

1856. Shelley, Charles Percy Bysshe, 21 Parliament Street, Westminster, S.W.

1859. Shuttleworth, Joseph, Stamp End Works, Lincoln.

1851. Siemens, Charles William, 3 Great George Street, Westminster, S.W.

1847. Sinclair, Robert, Eastern Counties Railway, Stratford, London, E.

1857. Sinclair, Robert Cooper, Tame Valley Colliery, Wilnecote, near Tamworth.

1859. Slater, Isaac, London and North Western Railway, Carriage Department, Saltley, near Birmingham.

1853. Slaughter, Edward, Avonside Iron Works, Bristol.

1859. Smith, Charles Frederic Stuart, Mining Engineer, Cinder Hill, near Nottingham.

1854. Smith, George, Wellington Road, Dudley.

1847. Smith, Henry, Spring Hill Works, Birmingham.

1858. Smith, Isaac, 36 Lancaster Street, Birmingham.

1847. Smith, Josiah Timmis, Windmill End Furnaces, Dudley.

1859. Smith, Matthew, Fazeley Street Wire Mills, Birmingham.

1857. Smith, William, 19 Salisbury Street, Adelphi, London, W.C.

1857. Snowdon, Thomas, Tees Side Iron Works, Middlesborough.

1859. Sokoloff, Capt. Alexander, Engineer, Russian Imperial Service, Steam Marine Department, Cronstadt.

1858. Sörensen, Bergerius, Engineer-in-Chief, Royal Norwegian Navy Department, Horten Dockyard, Norway.

1859. Spencer, John Frederic, 1 Adelaide Place, London Bridge, London, E.C.

1853. Spencer, Thomas, Old Park Works, near Shiffnal.

1854. Spencer, Thomas, Newburn Steel Works, Newcastle-on-Tyne.

1855. Stenson, William, Jun., Whitwick Collieries, near Ashby-de-la-Zouch.

1859. Stewart, Charles P., Messrs. Sharp Stewart and Co., Atlas Works, Manchester.

1851. Stewart, John, Blackwall Iron Works, Russell Street, Blackwall, London, E.

1857. Stokes, Lingard, Locomotive Superintendent, East Indian Railway, Howrah, Calcutta.

1859. Swingler, Thomas, Victoria Foundry, Litchurch, near Derby.

1859. Tannett, Thomas, Victoria Foundry, Leeds.
1858. Taylor, James, Clarence Iron Works, Leeds.
1858. Taylor, James, Britannia Works, Cathcart Street, Birkenhead.
1858. Taylor, Thomas John, Earsdon, near Newcastle-on-Tyne.
1848. Thompson, Isaac, Queensferry Colliery, near Flint.
1857. Thompson, John Taylor, Messrs. R. and W. Hawthorn, Forth Banks, Newcastle-on-Tyne.
1857. Thompson, Robert, Haigh Foundry, near Wigan.
1852. Thomson, George, Crookhay Iron Works, Westbromwich.
1858. Thomson, William, Jun., Railway Foundry, Normanton.
1848. Thornton, Robert, St. Leonard's Iron Works, Edinburgh.
1847. Thornton, Samuel, Bradford Street, Birmingham.
1857. Tomlinson, Joseph, Jun., Locomotive Superintendent, Taff Vale Railway, Cardiff.
1856. Tosh, George, Locomotive Superintendent, Maryport and Carlisle Railway, Maryport.
1856. Truss, Thomas, Shrewsbury and Chester Railway, Carriage Department, Chester.
1859. Turner, Edwin, Bowling Iron Works, near Bradford, Yorkshire.
1849. Turton, Thomas Burdett, Sheaf Works, Sheffield.
1856. Tyler, Capt. Henry Wheetley, R.E., Railway Department, Board of Trade, Whitehall, London, S.W.

1856. Vernon, John, Iron Ship Building Yard, Brunswick Dock, Liverpool.

1856. Waddington, John, New Dock Iron Works, Leeds.
1856. Waddington, Thomas, New Dock Iron Works, Leeds.
1847. Walker, Thomas, Patent Shaft Works, Wednesbury.
1856. Waller, William, Uddingstone, near Glasgow.
1856. Wardle, Charles Wetherell, Boyne Engine Works, Hunslet, Leeds.
1852. Warham, John R., Iron Works, Burton-on-Trent.
1847. Weallens, William, Messrs. R. Stephenson and Co., South Street, Newcastle-on-Tyne.
1857. West, Frank W. S., East Indian Railway, Calcutta.
1856. Wheeldon, Frederick R., Highfields Engine Works, Bilston.
1859. Whitham, James, Perseverance Iron Works, Kirkstall Road, Leeds.
1859. Whitham, Joseph, Perseverance Iron Works, Kirkstall Road, Leeds.
1847. Whitworth, Joseph, Chorlton Street, Manchester.
1859. Wickham, Henry Wickham, M.P., Low Moor Iron Works, near Bradford, Yorkshire.
1859. Wickham, Lamplugh Wickham, Low Moor Iron Works, near Bradford, Yorkshire.

1847. Williams, Richard, Patent Shaft Works, Wednesbury.

1859. Williams, Richard Price, Great Northern Railway, Engineer's Office, King's Cross, London, N.

1850. Williams, Walter, Jun., Albion Iron Works, Westbromwich.

1858. Williams, William, London and North Western Railway, Locomotive Department, Crewe.

1856. Wilson, Edward, Oxford Worcester and Wolverhampton Railway, Worcester.

1858. Wilson, Edward Brown, 36 Parliament Street, Westminster, S.W.

1859. Wilson, George, Messrs. Cammell and Co., Cyclops Steel Works, Sheffield.

1857. Wilson, John, Spring Works, Hill Top, Westbromwich.

1852. Wilson, Joseph W., 9 Buckingham Street, Strand, London, W.C.

1857. Wilson, Robert, Bridgewater Foundry, Patricroft, near Manchester.

1859. Winter, Thomas Bradbury, 28 Moorgate Street, London, E.C.

1858. Wood, Nicholas, Hetton Hall, Hetton, near Fence Houses.

1848. Woodhouse, Henry, London and North Western Railway, Stafford.

1851. Woodhouse, John Thomas, Midland Road, Derby.

1858. Woods, Hamilton, Messrs. Allsopp and Sons, Burton-on-Trent.

1859. Wright, Benjamin, Saltley Works, Birmingham.

1848. Wright, Henry, Saltley Works, Birmingham.

1859. Wright, Joseph, Saltley Works, Birmingham.

1859. Wrigley, Francis, Queen's Chambers, 5 Market Street, Manchester.

1853. Wymer, Francis W., 5 Heaton Terrace, Elwick's Lane, Newcastle-on-Tyne.

1856. Yarrow, Thomas, Locomotive Superintendent, Scottish North Eastern Railway, Arbroath.

1856. Young, John, Hope Villa, Woodhouse Lane, Leeds.

HONORARY MEMBERS.

1848. Branson, George, Belmont Row, Birmingham.

1858. Budden, William Humphryes, Messrs. R. Stephenson and Co., South Street, Newcastle-on-Tyne.

1851. Clare, Thomas Deykin, Midland Railway Station, Lawley Street, Birmingham.

1848. Crosby, Samuel, Leek Street, Birmingham.

1850. Gwyther, Edwin, Belmont Row, Birmingham.

1857. Hawkes, William, Eagle Foundry, Broad Street, Birmingham.

1859. Holroyde, John Bailey, Cheapside, Halifax.

1858. Lawton, Benjamin C., Grainger Street, Newcastle-on-Tyne.

1856. Marshall, John, Low Moor Iron Works, near Bradford, Yorkshire.

1848. Peto, Sir Samuel Morton, Bart., 9 Great George Street, Westminster, S.W.

1856. Pettifor, Joseph, Midland Railway, Derby.

1859. Sherriff, Alexander Clunes, General Manager, Oxford Worcester and Wolverhampton Railway, Worcester.

1856. Singleton, William, Dock Street, Leeds.

1848. Warden, William Marston, Edgbaston Street, Birmingham.

1858. Waterhouse, Thomas, Claremont Place, Sheffield.

HONORARY LIFE MEMBERS.

1849. Hodgkinson, Eaton, Eaglesfield House, Great Clowes Street, Higher Broughton, Manchester.

1859. Leather, John Towlerton, Leventhorpe Hall, near Leeds.

GRADUATES.

1850. Glydon, George, Spring Hill Tube and Metal Works, Eyre Street, Birmingham.

1851. Potts, John Thorpe, 4 Crescent Place, The Grove, Camberwell, Surrey, S.

PROCEEDINGS.

JANUARY 26, 1859.

The TWELFTH ANNUAL GENERAL MEETING of the Members was held at the house of the Institution, Newhall Street, Birmingham, on Wednesday, 26th January, 1859; JOHN PENN, Esq., President, in the Chair.

The Minutes of the last General Meeting were read by the Secretary, and confirmed.

The Secretary then read the following

ANNUAL REPORT OF THE COUNCIL.

1859.

The Council have great pleasure, on this occasion of the Twelfth Anniversary of the Institution, in congratulating the Members on the satisfactory position and successful progress of the Institution.

The Financial statement of the affairs of the Institution for the year ending 31st December, 1858, shows a balance in the Treasurer's hands of £425 13*s.* 8*d.*, after the payment of the accounts due to that date. The Finance Committee have examined and checked the receipts and payments of the Institution for the last year, 1858, and report that the following Balance Sheet rendered by the Treasurer is correct.

(See Balance Sheet appended.)

The Council report with great satisfaction the continued increase in the number of Members that has taken place during the last year, the total number of all classes for the year being 341, of whom 16 are Honorary Members, and 2 are Graduates.

The Council have to report the decease of five Members of the Institution during the past year, namely :—

THOMAS FORSYTH, . . .	Manchester.
JOHN HENDERSON, . . .	Smethwick.
ALFRED STANISTREET JEE,	London.
JAMES MACGREGOR, . .	London.
FREDERIC GEORGE SPRAY,	St. Petersburgh.

The Council have the pleasure of acknowledging the following Donations to the Library of the Institution during the past year, and expressing their thanks to the Donors for the valuable and acceptable additions they have presented. The Council wish to urge especially on the attention of the Members the important advantage to the Institution of obtaining a good collection of Engineering Books, Drawings, and Models, for the purpose of reference by the Members personally or by correspondence; and they trust that this highly desirable object will be supported by the Members generally, that by their united aid it may be efficiently accomplished.

LIST OF DONATIONS TO THE LIBRARY.

Report on the Railways of the United States, by Capt. Douglas Galton, R.E.; from the Author.

Manual of Applied Mechanics, by Professor W. J. Macquorn Rankine; from the Author.

On the Resistance of Tubes to Collapse, by William Fairbairn; from the Author.

Experiments to determine the properties of some mixtures of Cast Iron and Nickel, by William Fairbairn; from the Author.

Reports of the British Association for the Advancement of Science, 24 volumes from the commencement; from the Association.

Memoirs of the French Institution of Civil Engineers, 10 volumes complete from the commencement; from the Institution.

Transactions of the Royal Scottish Society of Arts, Vol. V. Part I.; from the Society.

Memoirs of the Literary and Philosophical Society of Manchester, Vol. XV. Part I.; from the Society.

Transactions of the Institution of Engineers in Scotland; from the Institution.

Proceedings of the South Wales Institute of Engineers; from the Institute.

Journal of the Society of Arts; from the Society.

The Artizan Journal; from the Editor.

The Civil Engineer and Architect's Journal; from the Editor.

The London Journal of Arts; from the Editor.
The Mechanics' Magazine; from the Editor.
The Practical Mechanic's Journal; from the Editor.
The Engineer; from the Editor.
The Mining Journal; from the Editor.
The Railway Record; from the Editor.
Engravings of the Great Eastern Steam Ship, and of the Bullet Moulding Machinery at Woolwich Arsenal; from Mr. William Smith.
Model and Specimens of Wood Bearings for Screw Propeller Shafts; from the President.
A Standard Decimal 30-inch Steel Measure, and a Decimal Wire Gauge; from Mr. Joseph Whitworth.
Specimens of the Davy, Stephenson, and Clanny Safety Lamps; from Mr. Nicholas Wood.
Specimens of work from Wood-cutting Machinery at Woolwich Arsenal; from Mr. John Anderson.
Specimens of Uchatius Cast Steel and of the processes of its manufacture; from Mr. Thomas Spencer.
Model of a self-acting Boiler-Feeding Apparatus; from Mr. John Picking.
Specimen of a Steam Engine Indicator and Watchman's Detector; from Mr. Alfred Knight.
Models of a new construction of Railway Spring; from Mr. Thomas Hunt.
Specimens of India-rubber Pump Valves; from Mr. John Hosking.

The Council have great satisfaction in referring to the large number of papers that have been brought before the Meetings during the year, and the practical value and interest of many of the communications, which form a valuable addition to the Proceedings. The Council request the special attention of the Members to the importance of their aid and cöoperation in carrying out the objects of the Institution and maintaining its advanced position, by contributing papers on Engineering subjects that have come under their observation, and communicating the particulars and results of executed works and practical experiments that may be serviceable and interesting to the Members; and the Council invite communications upon the subjects in the list appended, and other subjects advantageous to the Institution.

The following Papers have been read at the Meetings during the last year:—

On an improved system of Moulding and Casting; by Mr. Robert Jobson, of Wordsley.

Description of Wrigley's Friction Coupling for Shafting; by Mr. Benjamin Fothergill, of Manchester.

On Oil Mill Machinery; by Mr. Alexander Samuelson, of Hull.

Description of two pair of Horizontal Pumping Engines; by Mr. Edward A. Cowper, of London.

Description of Lemielle's Ventilating Machine for Mines; by Mr. Samuel Lloyd, Jun., of Wednesbury.

Description of a Hydraulic Shearing Press; by Mr. Charles Little, of Derby.

On Wood Bearings as applied to the Shafts of Screw Steam Vessels; by the President, John Penn, Esq.

On a new Dynamometer and Friction Break; by Mr. William Froude, of Dartington.

Description of Waterhouse's Compressed Air Forge Hammer; by Mr. Charles Beyer, of Manchester.

On Water Pressure Machinery; by Mr. William G. Armstrong, of Newcastle-on-Tyne.

On the Manufacture of the Uchatius Cast Steel; by Mr. Thomas Spencer, of Newburn.

Description of a Floating Steam Corn Mill and Bakery; by Mr. William Fairbairn, of Manchester.

On a new construction of Railway Springs; by Mr. Thomas Hunt, of Crewe.

On an improved construction of Axleboxes and Coupling Rods for locomotive engines; by Mr. William A. Fairbairn, of Manchester.

Description of an improved Railway Switch; by Mr. John A. Haswell, of Gateshead.

On the improvements and progress in the Working and Ventilation of Coal Mines in the Newcastle-on-Tyne district within the last fifty years; by Mr. Nicholas Wood, of Hetton.

On some applications of the Copying or Transfer principle in the production of Wooden articles; by Mr. John Anderson, of Woolwich.

On improvements in Pump Valves; by Mr. John Hosking, of Gateshead.

Description of the Locomotive Engine Shed and Turntables at the Gateshead station; by Mr. Edward Fletcher, of Gateshead.

Description of a Safety Hoist Governor; by Mr. Benjamin Fothergill, of Manchester.

On the burning of Welsh Steam Coal in Locomotive Engines; by Mr. Joseph Tomlinson, of Cardiff.

Description of a Direct-Acting Expansive Steam Engine; by Mr. Thomas T. Chellingworth, of Westbromwich.

The Council have particular pleasure in referring to the very successful and interesting meetings held in Newcastle-on-Tyne in the summer of last year, and in expressing their thanks to the Local Committee, and especially to their Chairman, Mr. Armstrong, and the Local Secretary, Mr. Haswell, for the excellent and spirited reception that was given to the Members of the Institution on that occasion; and the Council anticipate important advantages from the continuance of such meetings, both there and in other districts of the country.

The President, Vice-Presidents, and Officers of the Institution, and five of the Members of the Council in rotation, will go out of office this day, according to the rules of the Institution; and the ballot will be taken at the present annual meeting for the election of the Officers and Council for the ensuing year.

SUBJECTS FOR PAPERS.

STEAM ENGINE BOILERS, particulars of construction—form and extent of heating surface—relative value of radiant surface in effect and economy—cost—consumption of fuel—evaporation of water—pressure of steam—density and heat of steam—superheated steam, simple or mixed with common steam—pressure gauges—safety valves—water gauges—explosion of boilers, and means of prevention—effects of heat on the metal of boilers, low pressure and high pressure—steel boilers—incrustation of boilers, and means of prevention—evaporative power and economy of different kinds of fuel, coal, wood, charcoal, peat, patent coal, and coke—moveable grates, and smoke-consuming apparatus, facts to show the best plan, and results of working—plans for heating feed water.

STEAM ENGINES—expansive force of steam, and best means of using it—power obtained by various plans—comparison of double and single cylinder engines—combined engines—compound cylinder engines—comparative advantages of direct-acting and beam engines—engines for manufacturing purposes—horizontal and vertical—condensing and non-condensing—injection and surface condensers—air pumps—governors—valves, bearings, &c.—improved expansion gear—indicator diagrams from engines, with details of useful effects, consumption of fuel, &c.—contributions of indicator diagrams for reference in the Institution.

PUMPING ENGINES, particulars of various constructions—Cornish engines, beam engines with crank and flywheel, direct-acting engines with and without flywheel—size of steam cylinder and degree of expansion—number and size of pumps, and strokes per minute—speed of piston—pressure upon pump—effective horse power and duty—comparison of double-acting and single-acting pumping engines—construction of pumps—plunger pumps—bucket pumps—particular details of different valves—india-rubber valves, durability and results of working—diagrams of lift of valves—application of pumps—fen-draining engines—comparative advantages of scoop wheels and centrifugal pumps, lifting trough, &c.

BLAST ENGINES, best kind of engine—size of steam cylinder, strokes per minute, and horse power—details of boilers—size of blowing cylinder, and strokes per minute—pressure of blast, and means of regulation—construction of valves—improvements in blast cylinders—rotary blowing machines—indicator diagrams from air main and steam cylinder.

MARINE ENGINES, power of engines in proportion to tonnage—different constructions of engines, double-cylinder engines, trunk engines—use of steam jackets—dynamical effect compared with indicator diagrams—comparative economy and durability of different boilers, tubular boilers, flat flue boilers, &c.—brine pumps, and means of preventing deposit—weight of machinery and boilers—kind of paddle wheels—speed obtained in British war steamers, in British merchant steamers, and in Foreign ditto, with particulars of the construction of engines with paddle wheels, &c.—screw propellers, particulars of different kinds, improvements in form and position, number of arms, material, means for unshipping, bearings, horse power applied, speed obtained, section of vessel—governors and storm-governors.

ROTARY ENGINES, particulars of construction and practical application—details of results of working.

LOCOMOTIVE ENGINES, express, passenger, and luggage engines—particulars of construction, details of experiments, and results of working—consumption of fuel—use of coal—consumption of smoke—heating surface, length and diameter of tubes—steel tubes—experiments on size of tubes and blast pipe—construction of pistons, valve gear, expansion gear, &c.—indicator diagrams—expenses of working and repairs.

AGRICULTURAL ENGINES, details of construction and results of working—duty obtained—application of machinery and steam power to agricultural purposes—barn machinery—field implements—traction engines, particulars of performance and cost of work done.

CALORIC ENGINES—engines worked by Gas, Gun-cotton, or other explosive compounds—Electro-magnetic engines—particulars and results.

HYDRAULIC ENGINES, particulars of application and working—pressure of water—construction and arrangement of valves, relief valves—construction of joints—hydraulic rams.

WATER WHEELS, particulars of construction and dimensions—form and depth of buckets—head of water, velocity, percentage of power obtained—turbines, construction and practical application, power obtained, comparative effect and economy.

WIND MILLS, particulars of construction—number of sails, surface and form of sails—velocity, and power obtained—average number of days' work per annum.

CORN MILLS, particulars of improvements—power employed—application of steam power—results of working with an air blast and ring stones—crushing by rolls before grinding—advantages of regularity of motion.

SUGAR MILLS, particulars of construction and working—results of the application of the hydraulic press in place of rolls—application of steam and water for extracting the last portion of saccharine matter—construction and working of evaporating pans.

OIL MILLS, facts relating to the construction and working, by stampers, by screw presses, and by hydraulic presses—particulars of crushing rollers and edge stones.

COTTON MILLS, information respecting the construction and arrangement of the machinery—power employed, and application of power—cotton presses, mode of construction and working, power employed—improvements in spinning and carding machinery, &c.

CALICO-PRINTING AND BLEACHING MACHINERY, particulars of improvements.

WOOL MACHINERY, carding, combing, roving, spinning, &c.

FLAX MACHINERY, manufacture of flax and other fibrous materials, both in the natural length of staple and when cut.

SAW MILLS, particulars of construction—mode of driving—power employed—particulars of work done—best speeds for vertical and circular saws—form of saw teeth—saw mills for cutting ship timbers—veneer saws—endless band saws.

WOOD-WORKING MACHINES, morticing, planing, rounding, and surfacing—copying machinery.

LATHES, PLANING, BORING, AND SLOTTING MACHINES, &c., particulars of improvements—description of new self-acting tools—engineers' tools—files and file-cutting machinery.

ROLLING MILLS, improvements in machinery for making iron and steel—mode of applying power—use of steam hammers—piling of iron—plates—fancy sections—arrangement and speed of rolls—length of bar rolled—manufacture of rolled girders.

STEAM HAMMERS—friction hammers—air hammers.

STAMPING AND COINING MACHINERY, particulars of improvements, &c.

PAPER-MAKING AND PAPER-CUTTING MACHINES, new materials and results.

PRINTING MACHINES, particulars of improvements, &c.

WATER PUMPS, facts relating to the best construction, means of working, and application—velocity of piston—construction of valves.

AIR PUMPS, ditto ditto ditto

HYDRAULIC PRESSES, facts relating to the best construction, means of working, and application—economical limit of pressure.

ROTARY AND CENTRIFUGAL PUMPS, ditto ditto ditto

FIRE ENGINES, hand and steam, ditto ditto ditto

SLUICES AND SLUICE COCKS, worked by hand or hydraulic power, ditto

CRANES, steam cranes, hydraulic cranes, pneumatic cranes, travelling cranes.

LIFTS for raising railway wagons—hoists for warehouses—safety apparatus.

TOOTHED WHEELS, best construction and form of teeth—results of working—power transmitted—method of moulding—strength of wood teeth.

DRIVING BELTS AND STRAPS, best make and material, leather, gutta percha, rope, wire, chain, &c.—comparative durability, and results of working—power communicated by certain sizes—frictional gearing, construction and driving power obtained—friction clutches—shafting and couplings.

DYNAMOMETERS, construction, application, and results of working.

STRENGTH OF MATERIALS, facts relating to experiments, and general details of the proof of girders, &c.—girders of cast and wrought iron, particulars of different constructions, and experiments on them—rolled girders—best forms and proportions of girders for different purposes—best mixture of metal—mixtures of wrought iron with cast.

DURABILITY OF TIMBER of various kinds—best plans for seasoning and preserving timber and cordage—results of various processes—comparative durability of timber in different situations— experiments on actual strength of timber.

CORROSION OF METALS by salt and fresh water, and by the atmosphere, &c.—facts relating to corrosion, and best means of prevention—means of keeping ships' bottoms clean—galvanic action, nature, and preventives.

ALLOYS OF METAL, facts relating to different alloys—use of aluminum.

FRICTION OF VARIOUS BODIES, facts relating to friction under ordinary circumstances—facts on increase of friction by reduction of surface in contact—friction of iron, brass, copper, tin, wood, &c.—proportion of weight to rubbing surface—best forms of journals, and construction of axleboxes—wood bearings—water axleboxes—lubrication, best materials, means of application, and results of practical trials—best plans for oil tests—friction breaks.

IRON ROOFS, particulars of construction for different purposes—durability in various climates and situations—comparative cost, weight, and durability—roofs for slips of cast iron, wrought iron, timber, &c.—best construction, form, and materials—details of large roofs, and cost.

FIRE-PROOF BUILDINGS, particulars of construction—most efficient plan—results of trials.

CHIMNEY STACKS of large size—particulars, form, mode of building, cheapest construction, &c.—force of draught, and temperature.

BRICKS, manufacture, durability, and strength—hollow bricks, fire bricks, and fire clay—perforated bricks, cost of manufacture, and advantages—dry clay bricks—machines for brick making—burning of bricks.

GAS WORKS, best form, size, and material for retorts—construction of retort ovens—quantity and quality of gas from different coals—oil gas, cheapest mode of making—water gas, &c.—improvements in purifiers, condensers, and gasholders—wet and dry gas meters—pressure of gas, gas exhauster—gas pipes, strength and durability, and construction of joints—proportionate diameter and length of gas mains, and velocity of the passage of gas—experiments on ditto, and on the friction of gas in mains, and loss of pressure.

WATER WORKS, facts relating to water works—application of power, and economy of working—proportionate diameter and length of pipes—experiments on the discharge of water from pipes, and friction through pipes—strength and durability of pipes, and construction of joints—penetration of frost in different climates—relative advantages of stand pipes and air vessels—water meters, construction and working.

WELL SINKING, AND ARTESIAN WELLS, facts relating to—boring tools, construction and mode of using.

TUNNELLING MACHINES, particulars of construction and results of working.

COFFER DAMS AND PILING, facts relating to the construction—cast iron sheet piling.

PIERS, fixed and floating, and pontoons, ditto ditto

PILE DRIVING APPARATUS, particulars of improvements—use of steam power—particulars of working—weight of ram and height of fall, total number of blows required—vacuum piles—compressed air system.

DREDGING MACHINES, particulars of improvements—application of dredging machines—power required and work done.

DIVING BELLS AND DIVING DRESSES, facts relating to the best construction.

LIGHTHOUSES, cast iron and wrought iron, ditto ditto

SHIPS, iron and wood—details of construction—lines, tonnage, cost per ton—water ballast.

MINING OPERATIONS, facts relating to mining—means of ventilating mines—use of ventilating machinery—safety lamps—lighting mines by gas—sinking pits—mode of raising materials—safety guides—winding machinery—underground conveyance—mode of breaking, pulverising, and sifting various descriptions of ores.

BLASTING, facts relating to blasting under water, and blasting generally—use of gun-cotton, &c.—effects produced by large and small charges of powder—arrangement of charges.

BLAST FURNACES, consumption of fuel in different kinds—burden, make, and quality of metal—pressure of blast—horse power required—economy of working—improvements in manufacture of iron—comparative results of hot and cold blast—increased temperature of blast—construction and working of hot blast ovens—pyrometers—use of waste gases.

PUDDLING FURNACES, best forms and construction—worked with coal, charcoal, &c.

HEATING FURNACES, best construction—consumption of fuel, and heat obtained.

CONVERTING FURNACES, construction of furnaces—manufacture of steel—casehardening, &c.—converting materials employed.

SMITHS FORGES, best construction—size and material—power of blast—hot blast, &c.—construction of tuyeres.

SMITHS FANS, and FANS generally, best construction, form of blades, &c.—facts relating to power employed and percentage of effect produced—pressure and quantity of air discharged—size and construction of air mains.

COKE AND CHARCOAL, particulars of the best mode of making, and construction of ovens, &c.—evaporating power of different varieties.

RAILWAYS, construction of permanent way—section of rails, and mode of manufacture—mode of testing rails—experiments on rails, deflection, deterioration, and comparative durability—material and form of sleepers, size, and distances—improvements in chairs, keys, and joint fastenings—permanent way for hot climates.

SWITCHES AND CROSSINGS, particulars of improvements, and results of working—advantages obtained by steeling points and tongues.

TURNTABLES, particulars of various constructions and improvements—engine turntables.

SIGNALS for stations and trains, and self-acting signals.

ELECTRIC TELEGRAPHS, improvements in construction and insulation—underground and submarine cables—mode of laying.

RAILWAY CARRIAGES AND WAGONS, details of construction—proportion of dead weight.

BREAKS for carriages and wagons, best construction—self-acting breaks.

BUFFERS for carriages, &c., and station buffers—different constructions and materials.

SPRINGS for carriages, &c.—buffing, bearing, and draw springs—range, and deflection per ton—particulars of different constructions and materials, and results of working.

RAILWAY WHEELS, wrought iron, cast iron, and wood—particulars of different constructions, and results of working—comparative expense and durability—wrought iron and steel tyres, comparative economy and results of working—solid wrought iron wheels.

RAILWAY AXLES, best description, form, material, and mode of manufacture—comparison of solid and hollow axles.

The communications should be written on foolscap paper, on one side only of each page, leaving a clear margin on the left side for binding, and they should be written in the third person. The drawings illustrating the paper should be on a large scale and strongly coloured, so as to be clearly visible to the meeting at the time of reading the paper; or enlarged diagrams should be added for the illustration of any particular portions.

INSTITUTION OF MECHANICAL ENGINEERS.

BALANCE SHEET.

For the year ending 31st December, 1858.

Cr.	£	s.	d.	*Dr.*	£	s.	d.
By Balance 31st December, 1857	407	12	7	To Printing and Engraving Reports of Proceedings	354	14	0
,, Subscriptions from 18 Members in arrear	54	0	0	,, Stationery and Printing	40	13	1
,, ditto from 276 Members for 1858	828	0	0	,, Office Expenses and Petty Disbursements	34	4	10
,, ditto from 1 Graduate for 1858	2	0	0	,, Expenses of Meetings	7	6	5
,, ditto from 50 New Members, entrance fees	100	0	0	,, Fittings, Furniture, and Repairs	36	11	4
,, ditto from 2 Members in advance for 1859	6	0	0	,, Travelling Expenses	21	12	6
,, ditto from 1 Life Member	30	0	0	,, Parcels	4	10	11
,, Sale of Extra Reports	66	10	7	,, Postages	37	6	2
,, Interest from Bank	9	19	9	,, Salaries	425	0	0
				,, Rent and Taxes	116	10	0
				,, Balance 31st December, 1858	425	13	8
	£1504	2	11		£1504	2	11

(Signed) J. E. CLIFT, EDWARD JONES, } Finance Committee.

26th January, 1859.

The CHAIRMAN moved that the Report of the Council be received and adopted, which was passed.

The CHAIRMAN announced that the Ballot Papers had been opened by the Committee appointed for the purpose, and the following Officers and Members of Council were duly elected for the ensuing year:—

PRESIDENT.

JOHN PENN, ...	London.

VICE-PRESIDENTS.

WILLIAM G. ARMSTRONG, .	Newcastle-on-Tyne.
JAMES FENTON, . . .	Bradford.
BENJAMIN FOTHERGILL, .	Manchester.
HENRY MAUDSLAY, . . .	London.
JOHN RAMSBOTTOM, . .	Crewe.
JOSEPH WHITWORTH, . .	Manchester.

COUNCIL.

In addition to the ten Members remaining in office.

ALEXANDER ALLAN, . .	Perth.
WILLIAM E. CARRETT, . .	Leeds.
ALEXANDER B. COCHRANE, .	Dudley.
EDWARD JONES, . . .	Wednesbury.
NICHOLAS WOOD, . .	Hetton.

TREASURER.

HENRY EDMUNDS, . . .	Birmingham.

SECRETARY.

WILLIAM P. MARSHALL, .	Birmingham.

The following New Members were also elected:—

MEMBERS.

DANIEL ADAMSON, . . .	Manchester.
EDWARD BECK, JUN., . .	Warrington.
GEORGE CLARK, . . .	Sunderland.
JOHN DIXON, ...	Bradford.
GEORGE ELLIOT, . . .	Houghton-le-Spring.
WILLIAM B. B. HARVEY, .	London.

William Ebenezer Marshall,	Leeds.
Charles May, . . .	London.
William Maylor, . . .	Liverpool.
William Moor, . . .	Hetton.
John Northcote Ryder, . .	London.
Charles F. S. Smith, .	Nottingham.
Matthew Smith, . . .	Birmingham.
Alexander Sokoloff, . .	Cronstadt.
Benjamin Wright, . . .	Birmingham.

The Chairman expressed his thanks for the honour conferred upon him by his election as President of the Institution for another year; and regretted that he had been prevented by the state of his health from attending the meetings as much as he had wished during the past year. He could assure the members that he had the interests of the Institution entirely at heart, and would endeavour to promote its welfare in every way in his power; he strongly felt the importance and great practical value of the Institution, and was highly gratified at its rapid and successful progress. He particularly regretted having been unable from ill health to be present at the Newcastle Meeting, and should have been very glad if he had been able to attend that interesting and successful meeting.

The following Paper was then read :—

ON THE PROGRESSIVE APPLICATION OF MACHINERY TO MINING PURPOSES.

By Mr. THOMAS JOHN TAYLOR, of Earsdon, Newcastle-on-Tyne.

In the following paper an attempt is made to trace the progressive application of Machinery to Mining purposes; more especially to the drainage of mines and raising of coal in the Newcastle coal district: a subject which must, it is conceived, prove interesting both to the mining and mechanical engineer, as involving not only one of the earliest employments of the steam engine, but also the first extensive use if not the invention of railways.

The inclined position of beds of coal is intimately connected with the mechanical means required for working and draining them. In some cases the beds rise or crop out to the surface or "day," as it is called; and in others they are buried with the associated strata at considerable depths below. As these strata rise from depths of 100, 200, 300 fathoms and upwards, along an inclined plane, broken by faults and interruptions, but still ultimately making their way out to the day, it is obvious that depth is a principal element in the consideration of the mechanical means required for working and draining the coal beds. In the "shoaler" mines, or those worked near the surface, the lifting of water, which is undoubtedly the miner's greatest enemy, is comparatively easy: so also is the raising of the coal to the surface: and, it may be added, the ventilation; for inflammable gas is hardly ever met with in mines worked near the day, though carbonic acid gas, known to miners as "stithe" or choke damp, is abundant in such mines. There are thus three distinct requirements for all mines,—drainage, raising of the coal, and ventilation; but their nature and extent vary in different portions of a coalfield, and hence become characteristic of particular epochs. By the old miner, the "old man" as he is called, who cannot be accused of any want of shrewdness in

comprehending his position, the shallow mines were easily worked, and drained by adits, many of the coal beds being found above the natural drainage levels of the country: in a middle period, when deeper mines were to be worked, a perpetual struggle arose for the necessary mechanical powers, a struggle resulting in many contrivances, some of which were, as will be seen, very ingenious: and thirdly, we arrive at the epoch of the steam engine, which has ever since continued to be the right arm of mining operations, and has also led to many other mechanical appliances as a natural consequence of the development it has given to mining.

Early period of Coal Mining.—The earliest and simplest plan of coal mining was that of a day drift or adit, along which both water and coals were brought, as shown in the diagram, Fig. 1, Plate 1: the coals were carried in the workings by men or boys, first by hand or on their backs, and afterwards, as an improved step, on sledges which were trailed along the "thill" or floor. The shafts sunk on the continuation of the forward workings supplied what ventilation was supposed to be needed, and were surmounted by the common winch or jack-roll worked by hand. The mode of conveyance from the pit was on the backs of horses or donkeys, which carried what is still called a "load" in some outlying districts: the pack-horse load, weighing about 2½ cwts., being the same in fact as the "coal boll," of which it is the origin; and the name carries us back to that not very remote period when there were neither railroads nor even accessible carriage roads for purposes of transit.

The early period of active coal mining in England extends from the twelfth to the beginning of the seventeenth century. There are many curious notices of coal in these times: amongst which may be mentioned that in the fourteenth century coals were sent from Newcastle to be used in sharpening the tools of the workmen employed in building Windsor Castle; coals having been made use of for smiths' and manufacturing purposes long before they were introduced for domestic consumption. To the latest portion of this period, namely the commencement of the seventeenth century, may be referred the employment of horses in drawing coals and water by whim gins: by

this substitution of horses for manual labour an additional power was gained. But the coal beds were becoming so rapidly exhausted near the outcrops that in the year 1610 Sir George Selby declared in his place in parliament, for the grave consideration of the legislature, that the Newcastle coalfield would be worked out in a period of 21 years. To us, who continue to raise, two centuries and a half after his time, 16 millions of tons yearly from this coalfield, such a statement appears remarkable enough; but the speaker alluded, it must be supposed, to the working out of the accessible portions of the coalfield, and his observation denotes the near approach of a period when it would be necessary to win the deeper coal: an object which, however desirable, there were at that time absolutely no known means of accomplishing.

With a view fully to appreciate the nature of the difficulties which the early mining adventurers had to encounter in regard to drainage, it may here be mentioned that, as a general rule, a greater weight of water than of coal is raised to the surface in the mines of Northumberland and Durham. In particular cases, such as that of Wylam Colliery and Percy Main Colliery near Newcastle, the weight of water raised has been nearly 30 times that of coal: in other cases 7 or 8 times the weight of coal. To very deep mines, especially when the top feeders have been stopped back by cast iron caissons or tubbing, this remark does not apply: but still, as a general and average result, a greater weight of water than of coal is required to be raised, without taking into account those cases in which water is found to excess, as in the half-indurated marly sand beneath the magnesian limestone of the county of Durham.

Middle period of Coal Mining.—In the middle period of coal mining, or during the whole of the seventeenth and commencement of the eighteenth century, there was a perpetual struggle to obtain some mechanical power which might prove adequate to win and work the mines lying to the deep. In the absence of this power attempts were made to stop back the top feeders by caissons or "tubbing" as it was called. The first attempt of this kind is mentioned by William Waller, in his account of the mines of Sir Carbery Price, 1698. In

the preface to this work he ascribes to Sir Humphrey Mackworth the credit of applying, at his mines in Glamorganshire, "a *new* method of coffering out the water from his shafts and sinking pits, and thereby preventing the charges of water engines, and also recovering a large vein of coal by that means, which was in vain attempted by other artists." In the "Complete Collier," published in 1708, is a description of "the stopping back of shaft feeders with wooden frames;" and the author (name unknown) also says that he has heard of "iron frames that have been used at Harraton in Durham, made square and deeper than the thickness of the quicksand, to put back these quicksands, which may be of good use, though they must be dear." It was not however until 1795 that cast iron tubbing came much into vogue: in that year Mr. Barnes employed it at Walker Colliery near Newcastle, the pieces consisting of entire circular rims the size of the shaft. In 1796 Mr. Buddle adopted the more convenient plan of segments, at first connected together by screw bolts, but afterwards by wedging the joints, each segment constituting in fact the voussoir of a circular arch. By this means very large water feeders are dammed back, giving in some cases a pressure of 300 to 500 feet head of water.

In reference to the introduction of machinery, the "Complete Collier" (1708) furnishes a clear view of the state of mining at that time: it states, "in some places we draw water by water, with water wheels or long axle-trees, but there is not that convenience of water everywhere." The long axle-trees referred to worked chain pumps, as shown in the old sketch Fig. 2, Plate 1: an endless chain turned upon a large axle, having attached to it a number of oblong wooden buckets or troughs, which filled at the bottom of the pit and discharged at the top as they turned over the great axle-tree. When there was sufficient water for working the wheel, the full complement of buckets was placed upon the chains; but as the water decreased, a proportionate number of alternate buckets were detached, for the purpose of regulating this rude machine according to the power available. None of the buckets were more than half full at the time of discharging at the top, owing to the leakage and the vibration of the chains, the water continually pouring down the pit like a deluge. Wind was also

employed as a moving power: but then, as the author of the "Complete Collier" remarks, "the wind blows not to purpose at all times." Under these circumstances he falls back upon the methods then in use as being the best, namely the jack-roll and the horse gin; which last, provided with tubs and worked by two horses, "is found to be more serviceable and expeditious to draw both water and coal than any other we have seen in these parts yet." He is however obliged reluctantly to admit that he and his brethren knew of no means of draining "the good collieries which lie unwrought and drowned;" and that those who could discover such methods might, as he says, "keep their coach and six, for we cannot do it by our engines." But it is curious enough to observe that in speaking of the steam engine, then in its birth era, which was destined to realise the desideratum he had so much at heart, as well as so many other great objects, he expresses himself, as others have done both before and since his time, with caution and reserve respecting this new discovery. "There is," he says, "one invention of drawing water by fire, which we hear of, and perhaps doeth work to purpose, in many places and circumstances; but in these collieries hereaway I am afraid there are not many dare venture upon it, because nature doth generally afford us too much sulphurous matter to bring more fire within these our deep bowels of the earth, so that we judge cold inventions of suction and force would be safest for this our concern."

It will be observed that all this time no such thing as a pump, either upon the common or the plunger principle, was even thought of. The fact appears to be that no man in the north of England or in Scotland was at that time capable of constructing a common pump. This circumstance may be gathered distinctly from the records of the family of Mar. In 1709 the earl of Mar sent his colliery manager to Newcastle, which was then, as now, regarded as a sort of head school of mining. From the manager's report it appears that the machines in use were, as already stated, water wheels and horse engines, with chain pumps for raising water and horse gins for raising coals: the common depth of the pits being from 120 to 180 feet and a few from 300 to 350 feet: the steam engine is not even alluded to. The earl called in the aid of George Sorocould, an engineer from Derby, to

assist and advise his plans. Sorocould recommended substituting pumps in place of chains and buckets. But when he went away, no man could be found who was able to put his plans in execution. The millwright of Montrose, John Young, who had been in Holland, was referred to as capable of giving advice; and after him "the mechanical priest of Lancashire." It would seem that the recommendation of these almost forgotten worthies produced its effect: for the chain and bucket engine was superseded by the water wheel, with cranks and beams working pumps.

For raising coals the horse gin was employed: the cog and rung gin, shown in the old sketch Fig. 3, Plate 1, was made use of at this period, as well as the common whim gin, and was worked with 4 inch ropes and tubs. For a pit of 300 feet depth, 8 horses were required, two at a time, and a spare shift of two horses; the coal was drawn in corves made of hazel rods with wooden bows, each corve carrying 14 to 15 coal pecks, equal to 4 cwts. of coal, and a day's work was 21 score or 420 corve loads: the weight raised from a pit was therefore 84 tons per day, being 10½ tons for each horse. At the present time it is not uncommon to raise 400 to 500 tons per day, from a single pit of three times the above depth; this quantity being raised in deep pits exceeding 900 feet depth by winding engines of from 80 to 120 horse power. The pits were numerous, a part of the system being in fact to have them so: it was cheaper to sink a new pit of the then moderate depths, than to convey or rather drag the coals a distance underground; and it became a kind of rule for this reason, and also on account of ventilation, that the pits should not be more than 500 to 600 feet from one another. This explains the occurrence of the great number of old shafts which are found, where coal beds have been worked near the surface.

On comparing the mining practice above described with that pursued in Germany at the same and even a much earlier period, it will be found that, until the epoch of the steam engine, the English system was by no means greatly advanced. It appears from Agricola's curious work, written in 1550, that at that period the applications of machinery in the German mines were both numerous and complicated. They had not only the common horse gin, but several applications of the water wheel, both for raising the produce of the mine, and for lifting

the water, as well by means of the common pump as by chain pumps and rag wheel work; they employed also the water wheel with double buckets arranged in reverse order, for the purpose of more conveniently changing its motion, a method not brought into use in the Newcastle coalfield until about two centuries afterwards. For ventilation they employed bellows with attached air tubes, and a variety of applications resembling in principle the fanner of the winnowing machines, instruments which are still in use for common purposes. They had also carriages with wheels underground, a notable feature of superiority over the sledges made use of in our coal mines. Their methods of conveyance at the surface were however unimproved: besides common wains, they continued to use sledges for this purpose; the ore was also carried on the backs of horses, of men, and even of dogs. However the pumping machinery described by Agricola as consisting of water wheels and cranks and beams continues to this day to be the simplest and one of the cheapest modes of draining mines, where sufficient water power can be obtained. The crank and flywheel are also old appliances, which appear again and again in Agricola's diagrams: Fig. 4, Plate 1, is an old sketch showing pumps worked by a water wheel with cranks. The flywheel was commonly applied at that time, as it has been since, to the common windlass or jack-roll. "The roll being once put in motion," says he, "is much helped, and rendered more easy to be turned, by the revolutions of the flywheel." He appreciates accurately the nature of the flywheel, as an equaliser of force, assisting the motive power at those points of the revolution where it becomes weakest: and this notion of its use is clearly indicated in his expression that "it was employed instead of another man."

The use of gunpowder for blasting rocks had not yet become common in England, though it had been employed for this purpose in Germany about the year 1665. The process made use of for mining very hard rocks before the introduction of gunpowder was that of either splitting them by fires of wood or charcoal, or rending them by an apparatus called the "stook and feathers"; a hole was drilled in the rock, and the feathers, which were two thin plates of iron thickening towards the lower extremity, were placed in it; a wedge was then driven home between them, until a fragment of the rock was torn off by its action.

During the seventeenth century and for a long time afterwards many ingenious shifts were adopted underground, to obtain coal lying below the common level of drainage: rifts were formed in the coal, and cuts made to the lower parts, from which the water was lifted up to the requisite level by baling it with wooden scoops or by such machines as were then used underground; the principal of these was the rag pump, shown in the old sketch Fig. 5, Plate 1, worked by hand, having a wooden pump-tree with endless chain and leathers, and lifting the water in stages, each generally from 8 to 12 feet lift. In this manner the miners sometimes succeeded in penetrating step by step a considerable way to the deep, so that more modern workings have often suddenly holed into these old mine wastes, in situations where much solid coal was expected to intervene, but where it had been already excavated by the industry of the "old man"; and these old workings, of which no plans or records are preserved, being filled with water, a great deal of damage as well as loss of life has from time to time resulted from the inundations which ensued from holing into them.

It thus appears that the principal machinery employed in winning and working collieries at the beginning of the last century consisted of the chain and rag pumps for lifting water, the moving powers being horses, water, and wind; and the horse gin for raising the coal.

To this middle period of mining belongs also the introduction of railways. Coals were previously carried from the pits to the river by carts or wains, which held about 8 coal bolls or 20 cwts. each, being rather more than the third part of a Newcastle chaldron of 53 cwts.; and the collieries of Kenton, Benwell, and Jesmond, near Newcastle, employed between 400 and 500 carts each in this expensive mode of conveyance. The earliest railways seem to have been constructed with a limited and definite object in view, that of increasing the load dragged by a horse; and accordingly the first coal wagons on the railway carried 42 cwts. of coals, a material improvement at all events upon the old coal wain: but still the leading establishments were large, as each single wagon required a man and horse, and for a long period the gradients were laid out with reference only to this state of circumstances. The railways were constructed of wood; the upper rail generally of beech, 4 inches square, resting upon longitudinal

sleepers; these again resting upon cross sleepers. The cost of construction was from £400 to £600 per mile, which however represented a much higher value at that time than at present, as may be judged of from the fact that a collier's wages were 1*s.* per day, while the overman had 8*s.* per week, and the viewer 15*s.* per week. The coal wagons resembled the modern chaldron coal wagon in shape, and were made of wood, the employment of which was then in fact a necessity: for the quantity of iron made in the kingdom did not for a long period after the introduction of railways amount to 20,000 tons yearly, though the annual quantity now manufactured is nearly 4 millions of tons. To the scarcity of iron must also be ascribed its very slow substitution for wood in railways. The application of the cast iron fish-bellied rail, and subsequently the malleable iron bar, were the work of a century and a half, during which the use of coke in place of charcoal for smelting gave so extraordinary a stimulus to the iron manufacture. So little was the possibility of applying coal or coke to the smelting of iron anticipated in early times, that there are upon record grants of wood to be made into charcoal for the purpose of smelting iron, in the districts of Stanley Burn and Crawcrook, which are situated upon the Newcastle coalfield. It now appears not a little strange to find wood growing upon a coalfield thus appropriated for making iron; but even the name of collier, now applied to a coal worker, meant originally a charcoal burner, and is so employed in the grants above referred to.

Third period of Coal Mining.—The commencement of the third period of coal mining in the early part of the eighteenth century is marked by the notable epoch of the introduction of the steam engine. The importance of the Northumberland and Durham coal trade at this period may be judged of from the fact that the annual shipments of coal from Newcastle averaged 475,000 tons, and from Sunderland 175,000 tons, the aggregate being 650,000 tons; employing 600 ships of about 80 Newcastle chaldrons each, and 4500 seamen and boys. Under these circumstances it is not surprising that the beds near the surface and above the natural drainage levels were being fast exhausted.

The earliest applications of the steam engine were directed solely to the drainage of mines; and during the first 40 or 50 years after its invention, it does not appear to have been thought of for any other purpose. Savery called his little publication in 1699 on this subject the "Miner's Friend"; but Newcomen and Crawley in 1710 were the first who rendered the engine suitable for practical applications. In 1713 an engine was constructed at Byker near Newcastle; and at very nearly the same time two others were erected in that neighbourhood, one at Washington Fell and the other at Norwood. The engines were at that time worked by attendants who opened and shut the valves, until Beighton of Newcastle in 1718 introduced a great improvement, by which they were rendered self-acting. Stewart observes that in 1714 only four steam engines were in existence, two of which were upon mines in Newcastle. A few years after this date an engine was constructed by John Potter of Chester-le-Street in Durham, for draining Edmonston Colliery, the particulars of which have been preserved: the cylinder was 29 inches in diameter and made of brass, as also were the buckets and clacks and one of the working barrels; the pumps, 9 inches in diameter, were made of elm hooped with iron; the boiler top was of lead. The introduction of the steam engine, imperfect as it still was, not only enabled deeper mines to be won, but also cheapened the cost of drawing water, as compared with that by horses, in the ratio of about 7 to 1. The pumps, at first of wood, were afterwards made of cast iron.

Long after the introduction of the double-acting engine, the work was distributed over the up and down stroke by means of a dead weight acting on a separate balance beam; and this old custom is still adhered to in some parts of the Newcastle district. A step in advance was the application of the V bob, as shown in Fig. 6, Plate 2, consisting of a V shaped radius link A vibrating on a centre, fixed at a short depth down the pit, by means of which the beam was made to lift from both ends, with corresponding sets of pumps in the pit: some of the older engines are still worked in this manner; Fig. 6 is a diagram showing the application of the V bob at Backworth Colliery near Newcastle. In a third improvement this oblique mode of applying the power was replaced by a direct lift from each end of the beam, a separate pit or

staple B being sunk for the purpose, as shown in Fig. 9, Plate 3, which represents the general pumping arrangements at the Hester Pit, Hartley Colliery near Newcastle. In this case the depth of the pit is 600 feet, the engine of 300 horse power, and the pumps 31 inches in diameter, made of wrought iron; the total cost of the engine and engine house was £12,750. The quantity of water raised is 750 gallons per minute, making 382,395,200 gallons or 1,707,120 tons in a year; the total working expenses, including 8960 tons of coal consumed, are £1575 per annum, exclusive of interest of capital: hence the cost of raising the water from a depth of 600 feet is 0·22*d.* per ton of water raised. In two other cases it is found that the cost is respectively 0·27*d.* and 0·21*d.* per ton of water raised 600 feet. The average is therefore 0·23*d.* per ton of water for 600 feet depth, which may be taken as the mean cost of pumping water in Durham and Northumberland, exclusive of interest and redemption of capital. Under the old system, as already stated, a horse could raise 10½ tons per day from a depth of 300 feet; and reckoning 4*s.* 6*d.* per day for the horse, driver, wear and tear of ropes, &c., this gives 5·14*d.* per ton raised 300 feet, or 10·28*d.* per ton raised 600 feet: while from the same depth the same weight is raised by the steam engine for 0·23*d.* Hence the cost is 45 times more by horses than by the steam engine: besides which the increased depths at which modern mines are worked render them absolutely inaccessible by horse power.

Attempts are being made to dispense with the cumbrous weight of beams, by placing the pumping engine vertically over the mouth of the pit, the pump rod being worked direct by the steam cylinder. A diagram of this arrangement is given in Fig. 7, Plate 2, showing the direct-acting pumping engine at Burradon Colliery near Newcastle. There are here two cylinders of 60 inches diameter and 6 feet stroke, having their piston rods connected at top by a crosshead, to the centre of which the pump rod is attached, passing down between the cylinders. The pump rod is made continuous throughout the entire series of pumps, passing through a stuffing box at the bottom of each working barrel, as shown in Fig. 8; there is thus only a single pump rod for the whole depth, instead of a separate rod for each set of pumps as required in the ordinary arrangement, thereby greatly reducing the dead load upon

the engine. The water is raised from a depth of 900 feet; and the total cost of the engine, pumps, and building was only £4600.

Pumping by a rotary motion is now much practised, especially in sinking pits: the crank engine being handier for application, while its greater number of strokes per minute has the effect of keeping the water better and more uniformly out of the bottom. Fig. 10, Plate 3, is a diagram showing the application of this method at Ryhope sinking near Sunderland.

But though the great mining problem was solved by the application of the steam engine in the early part of the last century for raising water from mines, the miner having been enabled by its means to win the deeper coal of the field, thus acquiring an entirely new mining territory, still many years elapsed before steam power was applied directly for raising coals: and in the mean time various mechanical means were employed for this purpose. The old horse gin continued in use, and commonly required 24 horses in a day, working four at a time; it was employed at Walker Colliery near Newcastle for a pit 600 feet deep. But it was evident that some substitute must be found for animal power at such great depths. Various applications of machinery were therefore devised, amongst which may be mentioned one by Mr. Menzies, consisting of a descending vessel containing water which overbalanced and brought to the surface a basket of coals; the water was then discharged at the bottom, and if there was not a day level it had to be pumped up again by the steam engine. Notwithstanding this disadvantage, the plan was a simple and effective one, and continues in a modified form to be employed to this day in other districts, though not on the Newcastle coalfield, especially where the water can be got rid of by day levels. Figs. 11 and 12, Plate 4, are an elevation and plan of a water balance machine now working at the Cwm Bargoed pit, Dowlais Iron Works, South Wales. The coal tram containing about 1 ton of coal is placed upon the top of the empty water bucket A at the bottom of the pit, and the empty tram on the bucket B at the top; this bucket upon being filled with water descends, raising the empty bucket A with the full coal tram. The water is supplied through the valve box C and air vessel by the Cornish pumping

engine used for draining the mine. The landing chain D is a flat three-link chain, working over a turned pulley E; the motion is controlled by a powerful break F, and the buckets are guided by $\frac{3}{4}$ inch long-link chains G. A single-link counterbalance chain H, of the same weight per foot as the landing chain D, is attached to the bottom of each bucket and hangs loose in the pit, for the purpose of balancing the landing chain. The pit is an upcast shaft, of about 600 feet depth; and the quantity of coal raised is from 250 to 300 tons per day of 12 hours. These water balance machines are extensively used in the Welsh ironworks, generally upon mines having free drainage, where they are a cheap means of raising materials. The cost of erection is small; and a breaksman is not required, as one of the landers at the top of the pit works the break. Even where the water for working the balance machine has to be pumped up by the engine, as in the above case, it is a cheap arrangement for moderate depths, when the quantity of material to be raised is moderate, say under 300 tons a day. The time occupied in filling the buckets limits the amount of work; and 300 tons a day may be taken as the maximum quantity that can be raised with safety by such a machine from a depth of 600 feet. The indirectness of application of the power is more than compensated for by the superior economy in the employment of steam in the Cornish pumping engine as compared with the ordinary high-pressure winding engine.

During the latter half of the last century water wheels were very generally used in raising coals: these were either single wheels, or with a double row of buckets set in reverse order, which enabled the motion to be reversed more expeditiously. Where water was not to be had at the surface, the steam pumping engine was made to pump the water which drove the water wheel; and an extra power was thus expended in lifting the water, equal to that required for raising the coals from the bottom of the shaft. The double water wheel erected at Walker Colliery near Newcastle by Smeaton in 1778, shown in Figs. 13 and 14, Plate 5, drew 30 corves, each containing 6 cwts. of coal, from a depth of 600 feet in an hour, being at the rate of 100 tons per day of 12 hours. In this apparatus a Newcomen engine was employed to pump water into a tank A, from which it was discharged on to the

wheel B by one of the two spouts CC alternately, the wheel having two sets of buckets set in opposite directions for giving a reversed motion; and the lander readily started and reversed the winding by pulling the cords D at the pit mouth, or stopped the wheel by the cord E putting on the break F. As late as the year 1797 there were still numerous water wheels, with rope rolls on the same axle, at work in the coal districts of Northumberland and Durham.

The application of the steam engine directly to winding is of recent date. The introduction of the steam winding engine has been the cause of material changes in the underground arrangements: for, by enabling much larger quantities to be drawn daily from a single pit, the necessity for sinking other pits is obviated; and this again has occasioned great improvements in the underground modes of conveyance with a view to increased facilities of transit. With fewer pits better roads are required, and also better ventilation: so certainly does one step in advance lead to others. With the large winding engines now used in the north of England, which are often of as much as 100 to 120 horse power, working upon a first motion, the average performance may be stated at 400 tons raised in 12 hours from a depth of 900 feet: this includes the time occupied in drawing the workmen. The average winding speed in the shaft is from 15 to 20 feet per second or 10 to 13 miles per hour. In some cases, but not universally, a heavy counterbalance chain is wound round a continuation of the axle of the flywheel, for the purpose of balancing the weight of the long length of rope and tubs full of coal, when in the act of being lifted from the bottom of the pit, against the short length of rope and empty tubs at the surface: the chain works either into a staple (or small pit) sunk for the purpose, or upon an inclined plane.

The double-cylinder winding engine is being introduced with success. Fig. 15, Plate 6, is an elevation of the double-cylinder horizontal winding engine now working at Burradon Colliery near Newcastle. In this case the flywheel and counterbalance chain are dispensed with, and the engine works the rope rolls direct by a first motion. The two cylinders are 26 inches diameter and 5 feet 6 inches stroke, coupled to cranks at right angles on the shaft of the rope rolls, which are 15 feet

6 inches diameter, working with a flat wire rope ⅜ inch thick and weighing about 16 lbs. per fathom or 2⅔ lbs. per foot. The pit being 900 feet deep, about 18 revolutions are required in winding; so that the diameter of the drum is increased from 15½ to 17½ feet. Each load consists of 25 cwts. of coal, and the time of drawing is just 30 seconds, making the average winding speed 30 feet per second or 20 miles per hour. The time occupied in drawing and changing the tubs is as nearly as possible 1 minute; and the actual winding power is therefore 75 tons of coals per hour from a depth of 900 feet. The engine is worked with high pressure steam of 35 lbs. per square inch.

The average cost of raising coals by winding engines, for raising a quantity of 400 tons per day, including maintenance of the wire ropes, coals for the engine, repairs of engine and boilers, and men's wages, is

0·70 *d.*	per ton	for	300	feet depth
1·07	...	...	600	...
1·43	...	...	900	...
2·02	...	...	1200	...

The average cost of maintaining the pair of wire ropes is £1 per year for each fathom of depth, or 3*s.* 8*d.* per foot per year.

The principle on which the flywheel and counterbalance chain are dispensed with in the double-cylinder engine is the same as that of employing two men or rather two half men instead of one in the original windlass: so long are principles, assumed three centuries ago, neglected before they are brought into practical operation. It is obvious that the double-cylinder engine with cranks at right angles to each other renders a counterbalance unnecessary, by enabling the power of the engine to follow the crank throughout the entire revolution; and for the same reason the flywheel as an equaliser of the power is dispensed with.

After the introduction of the steam engine and its application to mining purposes as a means of drainage, the motive power of horses on railways was succeeded by that of fixed steam engines with ropes, and self-acting planes, methods which continue in use; but even so early as 1813 a locomotive engine was employed for leading coals along the Wylam colliery railway. The Newcastle coalfield was also the earliest scene of the genius of George Stephenson, whose first

locomotives were constructed in 1814 for the conveyance of coals along the Killingworth colliery railway, and with the Wylam engine may be regarded as constituting the commencement of that modern railway system which has been developed in so extraordinary and rapid a manner.

A circumstance which appears anomalous is the very late introduction of railways underground, which did not take place in England until about 60 years ago, a century after their employment on the surface. But this may be to a great extent accounted for by what has been already noticed respecting the sinking of pits: so long as they were sunk tolerably close together, the necessity for improved means of underground transit was not felt; but after deeper pits had been sunk and the distance of the workings from the shaft became consequently greater, the system of sledging, carried out first by manual labour and then by horses, gradually yielded to an imitation on a smaller scale of the wooden railways employed above ground, which enabled a horse to drag two or three of the basket corves instead of one only. By slow degrees cast iron and ultimately malleable iron rails were introduced; and as the last improvement, the carriages conveying the coals were brought from the face of the workings to the surface "on their own foot," that is without changing the mode of transit.

Horses and ponies are chiefly employed for the purpose of underground conveyance, and minute calculations have been made of the expense of this mode of conveyance. On a descending gradient of 1 in 144, the rails weighing 22 lbs. per yard, and the tubs carrying from 7 to 10 cwts. of coal each, a horse brings out 34 tons of coals per mile per day at a cost of 3·1*d.* per ton per mile, including haulage, maintenance of carriages and way, but not interest on capital of construction. The gross weight of a train in this case was 6½ tons, the weight of coals being 4 tons and the weight of the carriages 2½ tons. On the contrary with an ascending gradient, now rarely tolerated, the expense has been known to amount to 8*d.* per ton per mile. In either case the use of underground railways is a great improvement upon the previous sledge system, under which a horse's performance was not more than one tenth of its present amount. But

a cheaper mode of underground conveyance is still wanted, the cost being on the average three or four times as much as that by railways on the surface. In cases where coals are to be brought from distant workings, a steam engine placed at the bottom of the pit is sometimes employed; with an endless wire rope where the way is level, or double ropes where the gradient is sufficient to enable the empty train to overhaul the rope: and in this case the cost has been brought as low as 2*d*. per ton per mile. The self-acting inclined plane, first introduced by Mr. Barnes at Benwell Colliery near Newcastle in 1797, is also employed underground, an application for which it is peculiarly suited owing to the naturally inclined position of the strata.

With regard to the ventilation of mines, the agent employed for this important purpose in the Northumberland and Durham district is a rarefied column of air, heated by an underground furnace, or in a few cases by a furnace and chimney at the surface. The mechanical conditions established by the rarefaction can readily be calculated, as they depend upon the mean temperature and corresponding weight of the expanded or upcast column of air, compared with the weight of the cold or downcast column of air of the same length; the motive or ventilating power is thus easily ascertained. In the case of Haswell Colliery near Newcastle, for example, the observed mean temperature of the upcast shaft is 163° Fahr., and that of the downcast may be taken at 50°. The depth of the upcast shaft is 936 feet; and the weight of the upcast column of air of this length at 163° is the same as that of a column of 766 feet length of air at 50°: the expansion of air for each degree Fahr. being $\frac{1}{490}$th of its volume at 32°, or $\frac{1}{508}$th of its volume at 50°. Hence the column of air in the upcast shaft would stand if cold at a height of only 766 feet; and therefore the effect of the furnace is to lift the air through the further height of 170 feet, and this work is done upon the whole of the air passing up the shaft from the mine. The observed quantity of air passing through the mine is 94,960 cubic feet per minute of air at 50°, or 7407 lbs. per minute, the weight of 1 cubic foot of air at 50° being 0·078 lb. Therefore the useful horse power developed by the furnace is 7407 lbs. lifted 170 feet in 1 minute, or 1,259,190 lbs. lifted 1 foot in 1 minute, which divided by

33,000 gives 38 horse power as the ventilating power of the furnace. The coal consumed in the furnace is 8 lbs. per minute: hence the duty performed is 17,628,660 lbs. raised 1 foot high by 1 cwt. of coal. This is therefore the actual result obtained with the ventilating furnace at Haswell Colliery. At Seghill Colliery near Newcastle the duty is only 5,573,333 lbs. raised 1 foot high by 1 cwt. of coal: the quantity of air passing through the mine is 42,700 cubic feet per minute.

In both the above examples the rate of duty obtained with the ventilating furnace is low: and it may indeed be regarded as a remarkable circumstance that purely mechanical appliances have been so little used for ventilating mines. The writer is not aware of a single example of ventilation by mechanical means in the two great coal mining counties of Durham and Northumberland. Elsewhere mechanical appliances are in use for ventilating mines, and amongst them may be mentioned Struvé's mine ventilator, several of which are employed in the South Wales colliery district, at the Eaglesbush, Dyffryn, Risca, and other collieries. This ventilator is shown in Plates 7 and 8: Fig. 16, Plate 7, is a sectional elevation, and Fig. 17 a plan; Figs. 18 and 19, Plate 8, are vertical sections. The air is drawn from the mine by means of a pair of large aerometers AA, made of boiler plate and similar in construction to ordinary gasholders, each working up and down in a circular chamber of brickwork B, the bottom edge of the aerometer being immersed in an annular trough of water C in the walls of the chamber. At the top and bottom of each chamber are two sets of air valves I and O, consisting of simple wooden flaps hung upon vertical gratings, which open inwards on the side I communicating with the pit, and outwards on the opposite side O. In the up-stroke of the aerometer, the air from the pit D is drawn in along the passage E and enters below the aerometer through the bottom inlet valves I, while that above the aerometer is expelled through the top outlet valves O; in the down-stroke, the air below the aerometer is expelled through the bottom outlet valves O, while more air from the pit is drawn in above the aerometer through the top inlet valves I. The two aerometers are worked by cranks at right angles to each other, thus rendering the draught of air from the pit practically uniform.

Up to the present period the various machines employed for ventilating have not supplied the same quantity of air as is obtained by the underground furnace in well laid out coal mines, where the air channels are maintained in proper condition and are of an area in no case less than 40 square feet. However satisfactorily therefore some of these machines considered separately may have worked, they do not at present offer sufficient reasons for superseding generally the furnace ventilation. They are also liable to derangement, an important feature not applicable to the furnace; for even if the fire be extinguished, the heat of the upcast shaft is still sufficient to cause the circulation of a free air current for a period of some days. The simplicity of its construction is also a great argument in favour of the furnace, which thus continues, with all its inconveniences, to be the principal ventilating agent for mines.

The labours of the Mining Institute of Newcastle may be expected to conduce to the improvement of the ventilation as well as of the drainage and working of mines: and may probably be the means also of developing principles the importance of which cannot at present be appreciated, whether as regards economy of production or security against those terrible explosions of fire damp which continue to be the bane and reproach of modern mining.

Before the introduction of the safety lamp, mines liable to issues of fire damp were lighted by the steel-mill: by means of toothed wheels a rapid revolution was given to the steeled rim of a wheel, against which a piece of flint was at the same time held, and the stream of sparks produced was sufficient to give at least a feeble degree of illumination. The principle of this mode of lighting depends upon the circumstance that fire damp or light carburetted hydrogen requires the contact of flame for its ignition, and is not fired by merely incandescent substances or by very small points of flame. In this respect it differs from either hydrogen gas or the other compounds of carbon and hydrogen.

It has thus been endeavoured to trace the mechanical appliances of coal mining from the earliest periods down to the present time. At first, it has been seen, the beds of coal lying close to the surface were

worked by the simplest mechanical means; while in the gradual progress onward there is a corresponding improvement of machinery, resulting at last in the application of the most powerful agencies now in use. From the original jack-roll, adit, and pack horse, to the steam engine and the railway, the progress is not a little curious. The coal mines of Northumberland and Durham, which had so small a beginning, are now, according to an estimate based upon returns made to the coal trade office, drained and worked by 443 steam engines, representing 26,740 commercial horse power. The production last year was nearly 16 million tons of coal, being one quarter of the total produce of coal raised in Great Britain. If in the absence of accurate statistics a similar scale be assumed for general application, it will be found that the total coal production of Great Britain employs nearly 2000 steam engines, of an aggregate of 120,000 commercial horse power, but representing the actual work of about 300,000 horses: a singular contrast with the still recent period when two solitary pumping engines lifted the water from mines on the banks of the Tyne.

Mr. J. E. McConnell enquired, in reference to the different kinds of steam engines employed at collieries, whether the comparative advantages and economy of high-pressure non-condensing engines and low-pressure condensing engines had been ascertained.

Mr. Taylor said the comparison had not been specially made, and sufficient results had not been obtained to form a comparison at present; the application of the double-cylinder direct-acting engine to mining purposes had been only recently made in the Newcastle district, and it had not worked long enough yet to afford reliable results. It was however coming into extensive use, with the object of simplifying the machinery by dispensing with the heavy beams of the old pumping engines and substituting direct-acting crank engines.

The Chairman asked whether the double-cylinder engines referred to were expanding from one cylinder to the other.

Mr. TAYLOR replied they were only two independent cylinders, working cranks at right angles, so as to start at any point of the stroke. For drawing coal high-pressure non-condensing engines were generally used, on account of simplicity of construction; and wire ropes had now almost universally superseded the old hemp ropes, and were a great improvement in point of durability and economy. The cost of maintaining the pair of wire ropes was about £1 per year for each fathom in depth, or 3*s*. 4*d*. per foot; and the average cost of drawing coal, including maintenance of the wire ropes, engine power, and men's wages, for raising a quantity of say 400 tons per day, was 1·07*d*. per ton for 600 feet depth, and 2·02*d*. per ton for 1200 feet depth.

Mr. H. G. LONGRIDGE observed they were much indebted to Mr. Taylor for the information given in his interesting paper on the progressive application of machinery in working mines; and he would be glad to hear some further remarks on the present requirements of mining operations, and on the applications of machinery now in progress of extension. He thought there were great openings for improvement in pumping and mechanical ventilation; and in pumping direct off the crank motion there was an important advantage, particularly in sinking pits. Some of the present pumping engines, such as the large one at the Hartley Colliery, had a very heavy beam; and he thought this must waste much power, which would be prevented by the adoption of the direct-acting crank motion.

Mr. TAYLOR said they were endeavouring in several places to dispense with the cumbrous mass of beams and to pump direct off the crank: and at the Burradon Colliery there was a large pumping engine working directly over the pit. The crank pumping engines were now used extensively, but had as yet been tried only in sinking the pits, and not for any great depth, from fear of the effect of the strain produced on the crank shaft by a heavy column of water.

He thought there was the greatest room for improvements in the underground conveyance of coals, which cost at present three or four times as much as their conveyance above ground. The coal was at present drawn underground by stationary engine power with ropes, or by horses; and the idea had occurred whether some kind of locomotive

power might be practicable, perhaps worked by compressed air to avoid danger of fire. It would render valuable aid if the members of the Institution would turn their attention to the subject, to devise some suitable plan for the purpose.

Mr. F. J. Bramwell remembered an ingenious plan introduced many years ago by Mr. John Hague for conveying power from the surface down into a mine by means of exhausted air, for the purpose of working the underground inclines or raising water from the mine. The plan was probably not equal to pumps, where the power was within convenient distance for application; but there might be many situations where it would be useful, such as in remote workings, from the difficulty or expense of conveying power for ordinary pumps to the distance where it was required to be applied. In this plan the exhausting power was obtained by air pumps worked at the top of the pit by a steam engine, and an air main was carried down the pit to an oscillating winding engine placed at the head of the incline to be worked. For raising water from the mine, the same air main was connected with a series of close boxes, placed at about 20 feet height above one another and communicating together by water pipes with valves, a degree of exhaustion being maintained in the air main equivalent to a head of about 20 feet of water: the water was raised successively into these boxes by opening a communication between the air main and the alternate boxes simultaneously, exhausting the air from them, so that each exhausted box drew up the water from the box below; and then by reversing the communications when this set of boxes was filled, the air was admitted to them and exhausted from the boxes which had just been emptied of water, into which the water was thus raised from those last filled. Self-acting floats in the several boxes were used to reverse the communications without requiring machinery. This plan served a little also to aid the ventilation of the mine, by a portion of the bad air being removed through the boxes.

Mr. H. Maudslay thought the adoption of mechanical appliances for the ventilation of mines was a subject of much importance, and well deserved more consideration; the particulars of two plans had been already brought before the Institution, Nasmyth's large ventilating fan at Abercarn Colliery, and Lemielle's exhausting machine used in

the Belgian mines, both of which had been in successful operation for a considerable time. At the Exhibition of 1851 a good exhausting fan by Mr. Lloyd of London was shown; and also an exhauster by Mr. Fabry of Belgium, which was working at some mines near Charleroi and was stated to be found economical of power.

Mr. C. W. Siemens remarked that ventilation by machinery was extensively carried on in the coal mines of Belgium and the north of France; this mode had been successfully employed there for many years, and its application was being extended. The application of power by mechanical means was undoubtedly the cheapest, abstractly considered; for in furnace ventilation the whole mass of air that was to be set in motion had to be heated, instead of requiring only as much heat as was necessary for supplying the power requisite to put that mass in motion. The actual cost of fuel would of course influence the relative economy that could be effected, and would affect the question differently in different localities. The application of power by exhausted air vessels that had been referred to would also be expensive where fuel was not cheap, owing to the loss of power arising in exhausting air, both by the inherent imperfections of air pumps and by the leakage of long mains.

Mr. Taylor observed that there were certainly several good plans of mechanical ventilation, which had gone far towards accomplishing the object desired; Struvé's ventilating machine used in some of the South Wales collieries was a good one, having proved one of the most successful in working and in the quantity of air discharged. The total quantity of air however at present supplied for the ventilation of a mine by these mechanical means was comparatively small, amounting generally to only about 15,000 to 25,000 cubic feet per minute, none having maintained he believed a greater quantity than about 50,000 cub. ft. per min. in regular work: but with the furnace ventilation the quantity of air supplied by a single shaft was 100,000 cub. ft. per min., and reached as much as 150,000 cub. ft. per min.; and he thought this much exceeded what was practicable by mechanical means.

In all attempts at replacing furnace ventilation by mechanical appliances, there were three requisites to be kept in view:—1st, the same quantity of air to be supplied; 2nd, the supply to be equally

constant and free from risk of derangement; and 3rd, greater economy. He did not wish to maintain the absolute impracticability of some satisfactory mode of mechanical ventilation being ultimately arrived at, and should be very glad if it could be accomplished; for there were serious inconveniences connected with the present furnace ventilation, such as loss of heat by radiation and conduction from the upcast shaft, the corrosion to which the iron tubbing in the shaft was exposed, and the injury and derangement of the timber work in the shaft by the heat, particularly where the shaft was divided throughout by a wood brattice. There were particular cases also where mechanical ventilation was serviceable, as in sinking pits, to maintain the requisite ventilation until the mine was sufficiently opened to allow of the furnace being used for the purpose. But for general application to the dangerous mines in the north of England, where it was essential to maintain the ventilation without risk of derangement from stoppage of the machinery, he considered the furnace system would still be preferred.

Mr. C. W. Siemens thought that the mere actual quantity of air supplied by any ventilating apparatus should not be considered to affect the result; for if it were found that 10,000 cubic feet of air per minute could be supplied more economically by mechanical means than by furnace ventilation, the same economy would apply to a larger quantity, such as 100,000 cub. ft. per min.

Mr. Taylor feared that with mechanical ventilation a double apparatus would be required in order to provide against any accidental stoppage by having duplicate machinery ready to work at the moment; and the question of the total quantity of air to be supplied then became an important practical consideration, from the complication of machinery involved when the quantity was very large. At present the furnaces were simple and safe, however great the quantity of air might be; and even if the fire was entirely out for a day or more, the heat absorbed by the sides of the shaft would be sufficient to keep up ventilation for the time.

Mr. C. May considered that the simple question was by what means of applying the fuel could the required mass of air be moved in the cheapest and most efficient manner; he did not think that the plan of heating the entire mass of the air was the proper way of arriving at

this desideratum. And as regarded the quantity of air, if as much as 100,000 cubic feet per minute were required, he did not see why it could not be divided between three machines ; and out of the three machines he thought, considering the simple construction of machine required, two might be safely relied upon to be always at work : by such means mechanical ventilation might be made fully equal to the present furnaces in certainty and safety, whilst it would have advantages unattainable by the other plan.

Mr. E. A. Cowper observed that the fan possessed great capabilities for moving large quantities of air at a low pressure, and had important advantages in its simplicity of construction and freedom from risk of derangement ; it was also economical in the application of the power when properly proportioned. In some experiments that he had tried with a blowing fan 5 feet 6 inches diameter the useful effect was found to be 74 per cent. with the ordinary working pressure of about 7 inches of water : this result was obtained from a number of experiments, the power employed being accurately measured by means of a series of indicator diagrams taken from the steam engine when doing no other work than driving the fan ; the useful effect obtained from the fan being calculated from the area of the tuyeres blowing into the cupolas, and the pressure and corresponding velocity of the air. Now with the furnace ventilation it appeared from the investigations that had been made that a very small percentage of the power due to the consumption of the fuel was obtained as useful effect ; and therefore if by means of a ventilating fan 74 per cent. could be obtained of the useful effect developed by a steam engine, he thought a considerable margin would be given for economy in the fuel.

Mr. Taylor said he would be very glad to see the experiment fully tried on a large scale, as the experience of actual working would be the only way of fully determining the question ; there was of course great reluctance to change a plan that was known to answer for another on a different principle, since the safety of so great an extent of life and property was involved, more particularly in the large and fiery mines of the Newcastle district ; and a serious difficulty consisted in the great cost of any experiment which should be large enough really to determine the point.

Mr. C. W. Siemens remarked that, in reference to the comparison between the beam pumping engines and direct-acting engines, there seemed to be some ambiguity as to the power required to put the weight of the heavy beam in motion; the only loss of power arising from the weight of the beam would be the extra friction caused by the increased pressure on the rubbing surface of the beam gudgeons, for all the extra power required for putting the heavier mass into motion in the first portion of the stroke was returned again by dragging the beam forward in the latter portion of the stroke whilst the propelling power of the steam was diminishing.

Mr. H. G. Longridge thought that view could not be correctly applicable to the present case; for, if the friction of the beam were supposed to be greatly reduced by anti-friction rollers, so little power would then be required to keep the heavy body in motion that it would appear to approach the fallacy of a perpetual motion.

Mr. C. W. Siemens replied that a force proportionate to the inertia of the beam would be required to set it first in motion; but if it were supposed to be placed between two springs resisting its motion equally on each side of the central position, then the force originally imparted to the beam in starting it into motion would be spent in the compression of the opposite spring, and would be all returned again by the recoil of the spring if of perfect elasticity; and the beam would be propelled back to its first position with the same velocity as before, causing the similar compression and recoil of the other spring. The beam would thus continue to oscillate backwards and forwards like a pendulum, however heavy it might be, without any further power being required beyond what was necessary to overcome the friction of the bearings.

The Chairman proposed a vote of thanks to Mr. Taylor for his paper, which was passed, and expressed his sense that they were much indebted to him for the trouble he had taken in the preparation of his very interesting paper.

Mr. J. E. McConnell suggested the desirability of the comparison between high-pressure and low-pressure engines in the Newcastle district being followed out, as to their relative economy and advantages of application, which might form a good subject for a future paper; and he thought it would be very serviceable if returns could be obtained

of the working of the engines in that district and also in the Staffordshire and other districts, such as had been carried out in the case of the Cornish engines with such valuable results.

Mr. TAYLOR said he should be happy to follow up the subject by carrying out the comparison between the low-pressure and high-pressure engines of the district; and he thought the Mining Institute at Newcastle was likely to be very beneficial in promoting enquiry into the subject. In that district however they were in a somewhat peculiar position as regarded the cost of fuel for steam power, from the circumstance that the coal for the London market, the greater portion of the whole quantity raised, had to be carefully prepared by screening out the slack, which remained of so little value for any other purpose than burning under the colliery engine boilers or in the ventilating furnaces that it could be taken at only 2*s*. per ton in estimating the cost of fuel for those purposes. But in such a district as Cornwall the case was just the reverse, the fuel being there so dear that it was necessary to study the greatest economy in its consumption, to which other considerations had to give way; and the Cornish engineers had consequently attained a degree of perfection in their pumping engines that was not met with elsewhere, as shown by the effective results of their engines on a comparison with the respective quantities of fuel consumed.

The following Paper was then read :—

DESCRIPTION OF A DRY-CLAY BRICK-MAKING MACHINE.

BY MR. BENJAMIN FOTHERGILL, OF MANCHESTER.

This machine, which has been constructed by Messrs. Platt and Co. of Oldham, has accomplished the object of making bricks from dry clay with a precision, exactness, and rapidity of manufacture quite remarkable, and calculated to effect a complete revolution in building work.

The machine is now at work at Oldham, and the process of manufacture is carried on in the manner about to be described. The clay is taken from the bank in tramway trucks to a large shed or covered storehouse, in order to keep the machines at work in bad weather, when the clay cannot be got sufficiently dry; and under the shed floor is an arrangement of flues that can be heated to dry the clay as taken from the bank at all times. From this shed the dry clay is taken by an elevator A, Figs. 1 and 2, Plate 9, and shot into a hopper at the upper end of a revolving pulverising machine B, consisting of a screen fixed at a slight inclination from a horizontal position, and so constructed and arranged that the clay is pounded and forced through it by crushers, while all stones and other hard substances are rejected at its lower end.

The pulveriser is shown enlarged in Figs. 3 and 4, Plate 10. The fixed shaft C is set at a slight inclination from the horizontal, and the ends DD of the screen revolve upon it; to these ends are bolted the longitudinal bars EE round the circumference, forming the screen, which are of a wedge-shaped section so as to give a wider opening between them on the outer than on the inner side, to allow the pulverised clay a free escape. There are also attached to the shaft C within the ends of the screen two bearers FF connected by two longitudinal bolts, which carry a series of cast iron crushers or pulverisers GG, weighing about ¾ cwt. each: one bolt forms a fixed axis at the extremity of the pulverisers; and the other bolt acts as a

support for them, in such a manner as to allow a slight space between their extremities and the inner side of the screen bars E, to prevent actual contact when the machine may be working without clay. The screen is made to revolve at about 25 revolutions per minute by a pinion driving the wheel H fixed upon the upper end. The clay is fed in by the hopper I at the upper end, and by the rotary movement of the screen is carried forward and under the pulverisers G, which break up the lumps and press the clay out through the spaces between the bars E; but owing to the manner in which the pulverisers are arranged and supported they yield and rise when stones or other hard substances are passing under them, preventing any damage to the machine: and in consequence of the inclination at which the screen is set, the stones are gradually traversed through its entire length, and ultimately rejected at the lower end which is left open for the purpose.

The clay is then conveyed from under the pulveriser by an elevator K, Figs. 1 and 2, Plate 9, into a revolving conical screen or sifter L, shown enlarged in Figs. 5 and 6, Plate 10; from which it falls into the hopper of the brick press M, Plate 9, in a state of fine powder: any particles not passing through the meshes of the sifter L are rejected at its larger end and conveyed by a spout to a pair of small crushing rollers N, and thence back by the spout O to the foot of the first elevator A, where they are mixed with the crude clay, and go through the same process again.

The brick press is shown enlarged in Figs. 7 and 8, Plates 11 and 12; Fig. 7 is a front elevation, and Fig. 8 a transverse section. The side cheeks AA are fixed on the foundation plate and support the principal parts of the press. B is the frame or bed where the moulds are arranged and in which the bricks are formed. C is the sliding mould charger, to take the clay from the hopper D, to the brick moulds; an adjustable striker E is fixed upon the front of the hopper to gauge the charge of clay when being conveyed to the moulds by the forward motion of the lever F, which is actuated by the cam G, shown dotted in Fig. 8, fixed upon the bottom cam shaft H. The lower ram I rests upon and is actuated by the cam shaft H, and is formed with four pistons K upon the upper surface, each of which fits into a separate

brick mould. The top cam shaft L gives motion to the upper ram M, which is also formed with four pistons N upon the lower surface, exactly corresponding with the four lower pistons K and fitting into the same brick moulds. The two cam shafts are driven at the same speed by the spur wheels O which are driven by the pinion P.

The cams R S lift the upper ram M, and are so arranged as to produce two successive elevations and allow two falls of the ram and pistons in the formation of each series of four bricks made at each revolution of the machine. The first blow of the pistons, after being raised by the first cam R, drives the clay out of the four apertures in the mould charger C, which have been brought directly over the four brick moulds by the motion of the lever F; and compresses the clay into the moulds, thereby expelling the air from it: a very heavy blow is given by the pistons upon the clay, the total weight of the falling parts being nearly 1 ton. The pistons are then raised by the second cam S to a suitable height to allow the mould charger C to move back to its former position underneath the hopper D, for the purpose of being filled with another charge of clay. A second blow of the pistons then takes place, thoroughly condensing the clay in the moulds; and the final pressure to finish the bricks is then given on the top side by the pressing cams T acting upon the friction rollers U which are fixed on the upper ram M: this downward pressure is met by a simultaneous upward movement of the lower pistons K, given by the eccentric form of the bottom cam shaft H. The shaft H is also formed so as to raise the bricks up to the top surface of the mould bed B after the pressure is completed, whence they are removed to the table V by the forward movement of the mould charger C, when delivering the charge of clay for the next set of bricks. An india-rubber buffer spring X is placed in the upper ram M, to receive the concussion of the fall of the ram upon the cams R S, in case the machine should from any cause run without clay. By this arrangement of applying the pressure both below and above simultaneously the bricks are kept in continued motion, sliding through the moulds whilst the severe pressure of the cams is taking place; which gives a fine polished surface to the sides of the bricks, and ensures the angles being all filled up completely square.

The whole process is thus entirely self-acting, from the crude clay being fed into the pulveriser out of the drying shed, to the bricks being finished by the press ready for the clamp or kiln; and no waste of material takes place, other than the rejection of the stones by the pulveriser in the first process; and no process of drying the bricks being requisite, they are taken direct from the machine and stacked in the kiln ready for burning, thus avoiding all risk of damage from handling whilst in the unbaked state. The clay may be mixed with breeze or ashes, or chalk for white bricks, or other such substances, the machines working any sort of clay or mixture equally well; the press by its extreme pressure forms a perfect brick in the unburned state, and an uncommon hardness and closeness is obtained quite impracticable in hand-made bricks.

By this process of manufacture, within a quarter of an hour, clay may be taken from the shed in its crude state, and the bricks delivered by the press, taken by a tramway, and landed in the kiln ready to be burned in the usual way. Buildings have been erected with these bricks; and it is found that with care in setting the bricks the inside surface is as perfect as the outside, and is finished without any occasion for plaster. For bricks so perfectly formed it might be expected that great care would be required in manipulation, and the production must necessarily be slow. The reverse is however the case, and the following is the result of actual working. The machinery prepares the clay and completes the bricks at the rate of 30 bricks per minute or 1800 per hour; in one day of 10 hours' work 18000 are produced, giving a total production of 5,400,000 per year of 300 working days. Thus with a very moderate amount of attention paid to burning, which is rendered easy by the great firmness of the bricks, five millions of perfect bricks may be burned from one machine in a year; and reckoning interest of money for the outlay, plant, wages, rent of field, material, labour, and every other expense, the bricks, perfect and symmetrical as they are, are produced with the machine at a cost of only 12*s*. per thousand.

Mr. Fothergill showed a series of specimens of the several processes of the manufacture, and a working model of the brick press. He stated that he had seen the machine working several times, and the bricks in the kiln; and those exhibited were fair specimens of the regular make: he was struck with the completeness and ingenuity of the mechanical arrangements, the finished nature of the bricks, and the rapidity with which they were produced. The success of machinery for making bricks depended mainly on the preparation of the material, and this machine ensured that nothing but clay was put into the bricks, and all stones were entirely separated by the action of the pulveriser without any force being spent in crushing them, the clay being supplied to the moulds in a thoroughly uniform state for all the bricks. Also the action of the dies both from the top and the bottom, and their continued motion whilst the extreme pressure was taking place, was an important point, as it ensured the edges of the brick being finished full and sharp on both sides and prevented any risk of the brick sticking to the sides of the mould and producing roughness of the surface.

Mr. W. Smith thought the machinery was certainly ingenious and the bricks remarkably well finished in appearance; but he had some doubt as to the strength and durability of these or any other dry-clay bricks; he thought that these bricks, though more dense than the ordinary hand-made bricks from the great pressure they were subjected to, would not resist the same crushing weight as well burned stock-bricks; and he feared they would absorb much water, which would expose them to injury from the weather. All former attempts at dry-clay bricks had he believed the defect of not sufficiently resisting the action of the weather; and he thought there might probably be chemical reasons preventing dry clay from making as good bricks as moist clay.

Mr. W. A. Adams had employed some dry-clay machine-made bricks some years ago in building an engine chimney; but though they looked pretty well at first when fresh from the kiln, they were soon found to suffer from the weather, the edges and corners failing, and therefore he believed they would prove inferior in strength and durability to the ordinary bricks.

Mr. Fothergill asked whether those bricks were found to be uniform in texture when broken; for in pressed bricks, if the supply of material was not fed uniformly into the machine, there was a smaller quantity towards one side of the mould than the other, causing one side of the brick to receive less pressure than the other and to be consequently not so dense. He understood that the bricks now shown had been found to stand well after long exposure to the weather. The manufacture of bricks was an important subject for the application of machinery, and many ingenious attempts had been made to attain this object; and if machinery could be brought to bear satisfactorily for this purpose, it would prove a great advantage in certainty and economy of manufacture, being independent of the causes of fluctuation and delay occurring in hand-made bricks.

Mr. W. A. Adams said the bricks he referred to were made in that neighbourhood by machinery, and were compressed in the mould by some kind of screw or other press; they were he believed about the same in texture as those now shown, and these he observed appeared also to have a similar defect of softness at the edges.

Mr. C. May observed that in the manufacture of dry-clay bricks there were great practical difficulties to be overcome, which had in most cases proved much greater than they appeared at first in the application of machinery to the manufacture. But the most serious difficulty he believed in dry-clay bricks was in getting them burned sufficiently; they appeared to require considerably more burning than wet-made bricks in order to render them equally hard and strong. He had seen some American specimens of dry-clay bricks which were certainly very good and hard, but they had been burned nearly to the point of vitrification, their specific gravity being 2·3 or only 0·3 less than that of granite; these were small sized bricks, used for paving and fronting houses in New York. Many plans for making bricks by machinery had been tried in America; and he supposed the present machine was originally an American plan, as he remembered seeing a model of one from that country some time since, which was similar in its action to the present one, only the pressure was not applied from below as well as from above so as to keep the brick in motion in the mould.

Mr. G. F. Muntz remarked that an important point in the machine would be the construction of the moulds, as they would require to be kept up to a sharp edge in order to ensure good work; this had been found a difficulty in other machines from the wearing action of the clay. He asked whether the estimated cost of manufacture stated in the paper included the expense of keeping the moulds in complete repair.

Mr. Fothergill replied that the full cost of keeping in repair was included in the estimate: in other machines there was not the same provision for preserving the edges of the moulds, from the circumstance of the clay being made to slide across the edges of the mould in a partly solid state, which caused the edges to be worn away; but in this machine the clay went into the mould in a state of powder, and was compressed whilst in the mould, thus avoiding the wear of the edges. The faces of the moulds were formed of wrought iron plates casehardened, secured by pins, so that they could be easily removed and replaced when desired.

The Secretary observed that he had witnessed the working of the machine at Oldham described in the paper, and saw the bricks made and in the kiln; and could confirm the statement that had been made as to the completeness and rapidity with which the bricks were turned out from the machine, and that the specimens shown were fair samples of the work produced.

Mr. C. May feared from the experience of some large establishments for making bricks by machinery that the expense of wear and tear would prove a much heavier item than at first expected, on account of the extra exposure to wear that the machinery was subjected to from the nature of the material employed in the manufacture; and he thought the results of a year's continued working would be required to show the full amount. All the plans that he knew of had suffered from this difficulty, which had prevented them from producing dry-clay bricks for a moderate price in the long run, though they might do so for a short time after first starting; and at one establishment on a large scale near London, where a 100 horse power engine was employed for driving the brick-making machinery, the cost of manufacture, including wear and tear and interest on plant, turned out much greater

than was anticipated, and he understood it was found that the bricks could not be supplied at a profit in regular work under about 24*s*. per 1000. He doubted the possibility of supplying bricks in the long run from the present machine at much less cost, and feared the wear and tear alone would amount to 5*s*. per 1000 bricks. He asked what was the cost of the machine complete.

Mr. Fothergill replied that the whole of the machinery for preparing the clay and making the bricks was about £1000, complete for making four bricks at once as described, exclusive of the steam engine which was about 12 horse power, and the building.

Mr. J. Whitworth enquired what quantity of coal was used in burning the bricks, compared with burning ordinary bricks.

Mr. W. Richardson (from Messrs. Platt and Co. of Oldham) replied that the coal used was not quite so much as in burning ordinary bricks; but the bricks exhibited had not been burned quite hard enough, and should have remained in the kiln somewhat longer. In all former plans of making dry-clay bricks he believed the pressure had been applied on one side only; but in that mode of manufacture it was found that the bricks could not be made equally hard and sound on the underside, and an advantage was gained in the present machine by the pressure being applied simultaneously both above and below. In the screw presses previously used the top surface of the mould became worn by rubbing upon the grit contained in the clay; but in this machine the wear of the moulds was much reduced, on account of the mode in which the action of the die in the mould took place, and the repairs were rendered very simple by the construction of the moulds with moveable plates for the faces; he was satisfied that the cost of wear and tear would not exceed 1*s*. per 1000 bricks, but in the estimate of expense of manufacture it had been taken at 2*s*. per 1000. No doubt if the surfaces were not quite hard they would be subject to considerable wear on account of the dust and grit to which the rubbing parts were exposed; but the sides of the moulds were constructed of wrought iron case-hardened and made very hard, which was found the best suited for the purpose, steel being too brittle and cast iron not hard enough; the rubbing faces of the cams were cast in chills.

The Chairman asked how long the machine had been at work.

Mr. W. RICHARDSON replied that it was originally an American machine and had been working in the United States about 14 years; the present machine, which was an improvement by Mr. Platt, had not been long completed, and the first of the new machines had been sent out to India after being worked at Oldham for about a month; and another was recently started in its place at Oldham where it was now in regular work.

Mr. E. A. COWPER enquired what was considered the relative cost of hand-made bricks; he had made a quantity once for as low a cost as 12*s*. 9*d*. per 1000, but the average price would probably have to be taken at half as much more. He observed that in some of the earlier attempts in using machinery the bricks were simply moulded first and then pressed afterwards, and he did not know whether that was a process that could get them properly sound.

Mr. C. MAY said that in the neighbourhood of London, where bricks were made in the largest quantities and probably as cheap as anywhere, the cost could not be taken at less than about 18*s*. per 1000 at the kiln. In the application of machinery to the purpose a great difficulty to be encountered was the rough hands into which the machines had to go in the ordinary run of regular work; and little defects that would be attended to at once in a shop and set right before they could get far wrong, would be liable to be neglected until the working of the machinery was interfered with by requiring expensive repairs.

Mr. W. A. ADAMS remarked that in Minton's china manufacture the dry-clay process was used successfully for small articles such as buttons, which succeeded by being quite vitrified; but for plates or tiles he believed it had not been made to succeed, from the work not standing sufficient firing and losing its shape.

Mr. W. RICHARDSON said that in the use of dry clay for the brick machine the clay was not intended to be absolutely dry, but it was prepared just to that degree of dryness that it would not cake and that a clod would fall to pieces when hit with a maul. This was found to be the best condition of the clay for the purpose; it was essential that it should not be too dry, and there was in reality a considerable portion of moisture still in the clay when moulded into the bricks, as was shown by the surface and texture of the unburned brick.

Mr. J. Whitworth observed that one important point in the manufacture was evidently to get the exact degree of dryness throughout all the clay when put into the machine. He had seen, when in America at the New York Exhibition, a similar machine for making dry-clay bricks, which seemed to be working successfully; and he saw great numbers of the bricks made by the machine for sale, and also many houses built of these bricks which seemed standing well.

Mr. W. Richardson said the dry-clay bricks had been in use there about ten years, and had continued sound, and stood the weather satisfactorily.

Mr. C. W. Siemens suggested that as the principal difficulty with the bricks now shown appeared to be in getting them burned hard enough, it might be worth consideration whether some mixture of lime or other alkali with the clay might be employed advantageously to aid in the burning by causing the bricks to vitrify at a lower temperature.

Mr. Fothergill observed that his object in bringing the subject before the Institution was to communicate to the members what had been effected in the application of machinery to brick-making; as it was a particular advantage for the members to keep one another informed on the mechanical operations and inventions going on around, and to have the opportunity of discussing their merits.

The Chairman proposed a vote of thanks to Mr. Fothergill for his interesting paper, which was passed.

The Meeting then terminated, and in the evening a number of the Members and their friends dined together in celebration of the Twelfth Anniversary of the Institution.

PROCEEDINGS.

MAY 4, 1859.

The GENERAL MEETING of the Members was held at the house of the Institution, Newhall Street, Birmingham, on Wednesday, 4th May, 1859; HENRY MAUDSLAY, Esq., Vice-President, in the Chair.

The Minutes of the last General Meeting were read and confirmed.

The CHAIRMAN announced that the Ballot Papers had been opened by the Committee appointed for the purpose, and the following New Members were duly elected:—

MEMBERS.

WILLIAM JAMES ARMITAGE,	Leeds.
SAMUEL BASTOW,	West Hartlepool.
JOSHUA BUCKTON,	Leeds.
JOHN O. BUTLER,	Leeds.
WILLIAM CLAY,	Liverpool.
PETER BOYD EASSIE,	Lostwithiel.
WILLIAM FOWLER,	Chesterfield.
JOHN FRASER,	Leeds.
ALFRED CHARLES HOBBS,	London.
JAMES P. HUNT,	Birmingham.
FREDERICK WILLIAM KITSON,	Leeds.
JAMES KITSON, JUN.,	Leeds.
JOHN MANNING,	Leeds.
EDWARD BINDON MARTEN,	Stourbridge.
JAMES MURPHY,	Newport.

Henry Peet,	Carlisle.
George Banks Rennie,	London.
George Salt,	Bradford.
Isaac Slater,	Birmingham.
John Frederick Spencer,	London.
Thomas Tannett,	Leeds.
Edwin Turner,	Bradford.
James Whitham,	Leeds.
Joseph Whitham,	Leeds.
Richard Price Williams,	Leeds.
George Wilson,	Sheffield.
Francis Wrigley,	Manchester.

HONORARY MEMBERS.

John Bailey Holroyde,	Halifax.
John Towlerton Leather,	Leeds.

The following Paper was then read :—

DESCRIPTION OF THE PUMPING ENGINE AT THE NEWCASTLE WATER WORKS.

BY MR. ROBERT MORRISON, OF NEWCASTLE-ON-TYNE.

The Pumping Engine forming the subject of the present paper was constructed by the writer for the Whittle Dean Water Works, and has been erected near Benwell, a village about two miles west of Newcastle-on-Tyne, where filter beds and an extensive pure water basin have likewise been recently constructed. About ten miles west of Benwell, at Welton, there are eight extensive collecting and settling reservoirs, called the Whittle Dean reservoirs, containing at their ordinary high water level 600 million gallons of water, but capable of holding a much greater quantity. The average low water level of these reservoirs is 360 feet above the high water line in the Tyne, and the water is conducted into the towns of Newcastle and Gateshead through a 24 inch cast iron main by gravitation. Owing to the extension of these towns up the banks of the Tyne, considerable portions of them are above the level to which the water will flow direct from Welton. To supply these districts an engine and reservoir were constructed some years ago at Gateshead; which afterwards proving insufficient through the increased demand for water, the engine here described was erected, and can now at all times supply the highest districts by gravitation alone with an unlimited quantity of water.

Down the bank opposite Benwell, at about the level of high water in the Tyne, runs the 24 inch Welton main, from which a 10 inch branch has been led up the hill side a distance of 2240 feet to the filter beds already mentioned, which are placed at a level of 246 feet above high water line in the Tyne. The water passing from the beds to the pure water basin is conducted to the engine suction pipe, and is driven through another 10 inch main 3850 feet long into a second recently formed reservoir at the top of the bank at High Benwell,

412 feet above high water in the Tyne, from which the town is supplied through a 10 inch main. When it is not required to pass the water through the filtering beds or pure water basin, the 10 inch branch from the Welton main delivers the water direct into a well 20 feet deep, whence it is pumped by the engine as before to the second reservoir up the hill. The height from the bottom of the well to the end of the delivery pipe in High Benwell reservoir is 182 feet, which is the height the engine has been lifting during the experiments; for the depth of water in the well has generally been about equal to the depth of water in the high reservoir.

The pumping engine, which was erected twelve months ago, is a horizontal high-pressure expansive and non-condensing engine, working direct a double-acting pump, and coupled to a crank and flywheel. Figs. 1 and 2, Plates 13 and 14, are a longitudinal section and sectional plan of the engine and pump: Figs. 3 and 4, Plate 14, are transverse sections through the pump and through the steam cylinder.

The steam cylinder A is 26 inches diameter and 4 feet stroke; and the pump B, which is worked from the same piston rod, is 11½ inches diameter. A crosshead is keyed upon the piston rod and guided by a cylindrical slide C on each side, working on round guide rods DD carried by brackets from the bed plate; and the connecting rod E is coupled to the crosshead close to the piston rod F, which is lengthened sufficiently to allow the crank to clear the end of the pump B. The crosshead is made solid in one piece with the cylindrical guide on the side to which the connecting rod is attached, and the other side is made with a socket and keyed. Each guide C is provided with two set screws to allow of tightening up the brasses as they wear. The flywheel G is 16 feet diameter and 5½ tons weight. The pump B is double-acting, and has a solid piston fitted with cupped leathers facing both ways, with a brass piece between them to preserve the leathers from being cut. The pump valves H, shown enlarged in Figs. 5 and 6, Plate 14, are rectangular butterfly valves of india-rubber 1¼ inch thick, beating on ½ inch bars, with 1 inch spaces; the total area of opening in each valve seat is 112 square inches. The suction valves open from a chamber I in the bed plate to which the suction pipe K leads from the well; and a back flap valve

of india-rubber is fixed at the extremity of the pipe K at the bottom of the well, 20 feet below the pump suction valves. The delivery valves are exactly similar to the suction valves and immediately over them, and they are connected by a horizontal pipe L parallel to the pump B, from which the delivery pipe M leads off proceeding direct to the main. A branch is carried off obliquely from the main to the air vessel, which is situated outside the building and is 3 feet diameter and 12 feet high. Two small air vessels NN are also fixed on the top of the pump B, immediately over the two delivery valves.

The steam cylinder is fitted with a separate expansion slide O, working on the back of the ordinary slide valve P. This arrangement is shown enlarged in Figs. 7 and 8, Plate 15. Both slides are worked by fixed eccentrics, but the expansion is made variable by means of a slotted link R, vibrating on a centre fixed to the bed plate, and permanently connected to the rod of the expansion slide O, which is attached to the centre of the link, the eccentric rod being connected to a sliding block worked up and down the slot by means of a screw, which can be readily adjusted whilst the engine is at work. There is an index on the side of the link to show the degree of cut-off. The exhaust steam is discharged into a cistern S cast in the foundation plate, into which the cold feed water is injected through a perforated pipe T; by this means the feed water is heated and is then pumped from the cistern into the boiler. A glass gauge on the side of the cistern indicates the level of the water, as it is desirable that there should not be more than 3 inches depth in the cistern.

As the eccentrics are fixtures on the flywheel shaft and the rods permanently connected to the slide valves for the sake of simplicity and durability of construction, a special arrangement is provided for starting the engine by means of a two-way cock U, Fig. 7, attached at the bottom of the steam chest and connected by small branch pipes to both steam ports, by which the steam can be turned into either port beyond the valve and the engine readily started. There are three Cornish boilers with single flues, having the fire in the flue; the boilers are 28 feet long and 4 feet 9 inches diameter, and the flues 3 feet diameter; but only two boilers at a time are used for working the engine. The firedoors are arranged to admit any quantity of air,

and regulated in such a manner as to be under the control of the engineer; the result is perfect combustion and the entire absence of smoke with the Benwell pit coal.

The steam is maintained at 60 lbs. per square inch above the atmosphere, and the engine is usually worked with the steam cut off at ⅛th of the stroke. A specimen of the indicator diagram is shown in Fig. 9, Plate 15. The main slide P having always exactly the same motion, whatever be the degree of expansion, the opening of the exhaust and the amount of compression are constant. The usual speed of the engine is 24 revolutions per minute, or 192 feet per minute speed of piston; but it has been worked up to 40 revolutions, or 320 feet per minute of the piston. The pressure of water upon the pumps as indicated by a pressure gauge is 80 lbs. per square inch when standing, and rises to a mean of about 95 lbs. per square inch whilst working, equivalent to 18·6 lbs. per square inch effective pressure on the steam piston or 57 horse power effective. Taking the coals consumed for 3 months, the consumption is 30 cwts. per day of 12 hours, including lighting fires &c., or 5 lbs. of coals per effective horse power per hour, and 4 lbs. per indicated horse power per hour. It will thus be seen that the consumption of coals is not much more than if this engine had been a condensing one, whilst the first cost of the engine and building is much less, and the smooth and steady motion of the machine is much in its favour when compared with the beam engines.

The Chairman regretted that Mr. Morrison was unavoidably prevented from being present as expected. He observed that an independent starting apparatus was now in general use for large engines working expansively, having become requisite as a convenient mode of readily starting the engine. He enquired whether the starting cock described in the paper was used also as a blow-off cock.

The SECRETARY replied that it was only a two-way cock for starting the engine, and was found a simple and convenient plan for starting the engine with the expansion gear set to any required point of cut-off; but the sliding block could be readily adjusted while the engine was working, as the speed was not too great to prevent this. He had seen the engine at work, and had seen the indicator diagram taken; the engine worked very steadily and smoothly.

The CHAIRMAN remarked that the india-rubber pump valves shown in the drawings appeared to be fixed in the centre by the guard, so as always to beat on the grid in the same place; and he feared they would consequently be found to cut after working for some time, although india-rubber valves wore well when sufficient play was allowed for them to beat in a different place each time. The india-rubber valves used in marine engine air pumps were made circular and left free to turn on the centre spindle, to allow of shifting their position on the grids; and he thought it would be desirable to allow some play in the rectangular valves by fixing the india-rubber flap with slot holes, in order to diminish the wear by allowing it to shift a little on its seat. He enquired how long these india-rubber valves had been found to stand when used for water works purposes.

Mr. H. MARTEN said he had used Mr. Hosking's india-rubber ball valves for water works pumping engines under a heavy pressure, and found they answered well, as the balls dropped in a different position into the seating at each time of closing, so that the wear was distributed equally over the entire surface; some of the ball valves had now been at work for three or four years at the Hull Water Works, proving highly satisfactory in durability and working. He had also used Mr. Hosking's ring valves, having flat rings of india-rubber beating on circular gratings; in these the rings were left loose and free to turn, but appeared to beat always on the same part; they stood well, but he had not yet had long experience of their working. He had not tried rectangular butterfly valves of india-rubber, like those shown in the drawing; but feared that with a heavy pressure of water the india-rubber would be liable to wear out, and might be forced down into the openings of the grid so much as to lose its elasticity, unless it could be made proportionately thick for a heavy pressure. He thought a

circular valve would be much better than the rectangular form, so as to allow the valve to turn and beat in different parts.

Mr. J. FERNIE observed that it would be very advantageous for a general comparison to be made between the heavy beam engines previously employed for pumping and the lighter description of direct-acting engines that were now coming into general use, both as to cost of construction per horse power and consumption of fuel in working: the subject had been before the Institution several times, and descriptions had been given of large beam pumping engines, which were necessarily cumbersome and expensive in construction; while the present paper and others described a lighter and cheaper class of engine. It was desirable to ascertain what had been actually done with each construction of engine, as there was now a close competition between the heavy and light descriptions of engines; and he hoped the comparison between them would be taken up by some of the members, as the subject of a future paper.

Mr. A. B. COCHRANE thought it was an excellent suggestion, and was sure one of the members might be found to take up the subject in the manner suggested, well qualified by experience in connexion with direct-acting engines for pumping, and who had taken much interest in the introduction of smaller engines in place of large and heavy beam engines.

Mr. W. SMITH observed that the engine described in the paper presented a useful example of a simple construction of pumping engine, though there did not appear to him any novel features in it; he thought a different arrangement of the expansion gear would have been preferable, and that the hand screw in the vibrating link would be inconvenient for altering the degree of expansion unless the engine was working slowly. He would have been glad also to hear some further particulars of the working of the engine, as to economy of results compared with ordinary beam engines used at water works; and considered it would be very advantageous for such comparisons to be carried out as completely as possible.

Mr. J. FERNIE observed that the object desired in papers brought before the Institution was not novelty alone, but it was of perhaps greater importance to obtain authentic records of works successfully

executed, and indicator diagrams from engines, with correct particulars of consumption of fuel and work performed; he thought it was very important to encourage such communications, and the particulars of failures also proved sometimes of as great practical value as successful results.

The CHAIRMAN considered it was desirable to have as full details as possible of the comparative working and economy of all engines that were brought before the Institution; and expressed a wish for some further particulars of the comparative working of the engine described in the paper: he hoped some member would carry out fully the comparison suggested between direct-acting and beam pumping engines, in respect of weight, cost, economy of working, and other particulars, as it would prove of great value and interest. He proposed a vote of thanks to Mr. Morrison for his paper, which was passed.

The following Paper was then read:—

ON THE CONSTRUCTION OF HOT BLAST OVENS FOR IRON FURNACES.

By Mr. HENRY MARTEN, of Wolverhampton.

The first idea of Heating the Blast, prior to its entrance through the tuyeres into the furnace, is due, as is now universally admitted, to Mr. Neilson of Glasgow; who also has the merit of its first practical application early in the year 1829. Previous to that period the settled and firm conviction of ironmasters appears to have been that the colder the blast the better the quality and the larger the quantity of iron produced from each furnace in a given time. This conviction was the result of long continued observations, which showed that the produce per furnace was always more in winter than in summer; and as the difference most appreciable to the furnace managers between the one state of circumstances and the other was the temperature of the atmosphere, this without further investigation was at once charged as the sole cause. Subsequent research however has shown that the mere variation of temperature in the atmosphere from freezing point to summer heat had nothing to do with this result, which is owing to a cause still as actively in operation and as sensibly felt with the blast heated to a temperature of 600° or 800° Fahr.:— namely the excess of moisture, in the shape of invisible vapour, contained in the air in the warm weather as compared with the cold. So strongly rooted however was the belief that the temperature was the only circumstance affecting the make of iron, that the greatest efforts were made in summer to obtain the blast as cool as possible; amongst other plans, by passing it over cold water, with a result of course contrary to expectation, owing to a partial absorption of the water. On this point some most interesting evidence was adduced at the instance of Mr. Neilson in the great hot blast trial at Edinburgh in 1843: when all the leading and most experienced ironmasters of

the Staffordshire district—Mr. W. H. Sparrow of Stowheath, the late Mr. James Foster of Stourbridge, the late Mr. Barker of the Chillington Works, and the late Mr. Ward of Priestfield—stated it as a fact that previous to the introduction of hot blast the universal opinion of furnace managers was that the colder the blast the greater the produce of the furnace.

This being the state of practice and this the state of the science and opinion of men of skill in the iron trade, it occurred to Mr. Neilson, who was fortunately out of the trade and consequently unencumbered with either its practice or its prejudices, that the power of the blast in igniting the materials would be greatly increased, if in its passage to the tuyeres it were heated to a very considerable temperature. This idea was the result of careful and laborious thought on facts which came under his observation at the gas works at Glasgow, with which he was connected. Having convinced himself by experiment on a small scale of the correctness of the idea, he at once set about embodying it in a practical shape, the first application of the plan being at the Clyde Iron Works, Glasgow, early in 1829. By the kindness of Mr. Neilson the writer is able to present the Institution with a correct drawing of the apparatus then first made use of, which is shown in Figs. 1 and 2, Plate 16. It consisted of a small wrought iron heating chamber A, about 4 feet long 3 feet high and 2 feet wide, in construction similar to a wagon-head steam boiler, which was set in brickwork with a grate B below, similar in all respects to the ordinary steam boiler. The cold blast entered at the end immediately over the grate, and passed out to the tuyere from the other end, being warmed in its passage along the chamber to a temperature of about 200° Fahr. There was one of these heating chambers to each tuyere; the total area of firegrate per tuyere was about 4 square feet, and the area of heating surface of the chamber 35 square feet. This apparatus, although very imperfect and capable of raising the temperature of the blast to a very moderate degree only, was yet a very successful beginning; and the result produced in the blast furnace soon proved that the idea was one destined to work a vast change.

Although this first application of hot blast may now appear crude, it is doubtful whether, if divested of all subsequently acquired

experience, any better or more practical mode of testing the invention would have occurred to any one of us: so difficult is it to invent, so easy to see defects afterwards. The latter facility soon became apparent to Mr. Neilson; for the boiler plate chamber shortly succumbed to the heat and oxidation, and called for renewal. This being rather an expensive process, he began to look out for something more durable; and here fortunately his experience in gas making came to his aid: for finding that the cast iron gas retorts both endured a higher temperature and lasted longer under more trying circumstances than the boiler plate chamber, he at once resolved to substitute a cast iron retort-shaped heating vessel. This is shown in Fig. 3, Plate 16, and was found to be a great improvement on the original plan, lasting longer and raising the temperature of the blast to about 280° Fahr.: it was constructed at the Clyde Works about the latter part of 1829. It consisted of a cylindrical cast iron tube A, bottle-shaped at each end for the admission and discharge of the blast, about 2 feet 9 inches diameter and 6 feet long. As in the former case, there was one of these heating vessels to each tuyere; but the heating surface was increased to 55 square feet per tuyere, or one and a half times the surface exposed in the first application; and the grate area was increased to 11 square feet, or nearly three times. In the previous case it will be observed that the top of the wrought iron chamber was exposed to the atmosphere, thus leading to a great waste of heat. But in this second case a great improvement was made in the mode of setting, the heating vessel being wholly enclosed within the brick casing over the fire, thus preventing any waste of heat, and producing, with the increased heating and grate surface, the increase of temperature from 200° to 280° Fahr.

Having thus discovered the great advantage of this mode of setting the heating chamber entirely within the flue, but being still dissatisfied with the result at present obtained, and bent on further improvement, Mr. Neilson designed the greatly improved apparatus shown in Figs. 4 and 5, Plate 16, which was erected at the Clyde Works in 1830. In this plan there is a great extension of the previous idea. Instead of one grate per tuyere of 11 square feet area, there are here five grates BB for two tuyeres, giving an area of

28 square feet of grate surface per tuyere. The solitary tubular heating chamber over the grate is here lengthened out into a continuous pipe A, 18 inches diameter, enclosed in long lengths of flue, extending to a total length of about 100 feet, giving 240 square feet area of heating surface per tuyere. Much ingenuity is displayed in the arrangement and setting of both the grates, pipes, and flues of this apparatus; and it was attended with great success in raising the temperature of the blast to more than 600° Fahr., so as to melt lead. This may be called the first example of really hot blast being obtained.

Defects however soon began to manifest themselves. With the lengthening of the heating tubes and the greater general complication of the apparatus a difficulty had now crept in unawares, destined to be highly mischievous and to test the ingenuity of a whole generation of furnace managers: it arose from irregular and uncompensated expansion and contraction, inducing that serious defect of hot blast ovens, leaky joints. With the present experience in these matters it will be seen at once how very open an apparatus of the above construction would be to such a defect; the great length of pipe expanding and contracting to a perceptible extent at every change of temperature, and consequently straining every branch, bend, and joint of the whole range. The leakage at the joints was to some extent overcome by covering them with a ring of cast iron; followed as a result by the breaking of the pipes, a defect of greater magnitude. The very great improvement which took place in both the produce and the yield of the furnace, consequent on the increased temperature of the blast, made it necessary to set seriously to work to overcome the new difficulty, and to construct an apparatus capable of maintaining the heat of the blast uniformly at this increased high temperature without leakage or breakage of the pipes.

It was seen that the defects of this plan consisted principally:—1st, in exposing so great a continuous length of pipe to the action of the heat; thus augmenting the actual amount of expansion in each straight length of pipe, the effect of which would be concentrated upon the weakest point in that length; and at the same time subjecting the whole apparatus to all the ill effects of any irregular expansion or contraction of the heating main at any one point: 2nd, in such an

arrangement of the grates as was necessarily accompanied with an irregular action on the heating main at each time of successive firing and cleaning out: 3rd, in the evident inability of the ordinary flange joints to remain tight under these circumstances; since the excessive and repeated strains that they were subjected to, under the variations of temperature to which they were exposed, gradually ground the cement to powder and caused it to drop out from the joints. These formed very serious practical difficulties; and the problem presenting itself for solution, namely the construction of an apparatus capable of raising the blast to a temperature of 600° Fahr., and at the same time free from the above defects, must have been one involving most anxious consideration. An idea however at length occurred to Mr. Neilson, which approved itself to his mind, and has been the parent of all subsequent arrangements; namely the cast iron tubular oven.

The first practical realisation of the cast iron tubular oven is shown in Figs. 6 and 7, Plate 17, representing an oven erected at the Clyde Iron Works in 1832. In this case the irregular firegrates, five to two tuyeres, were done away with; and an oven with one grate only was constructed behind each of the tuyeres, now three in number, a tuyere A being at this time inserted at the back of the furnace, in addition to the two, one on each side, which were used before the introduction of hot blast. In the oven now constructed, the blast, instead of being carried as formerly along one continuous heating tube directly over the grate, was admitted into a main pipe C running longitudinally at one side of the grate B: on the top of this main pipe a number of deep circular sockets were cast with apertures into the pipe; and on the opposite side of the grate a similar main pipe D was fixed with corresponding sockets and apertures, which was connected with the tuyere pipe inserted into the furnace. The two longitudinal main pipes C and D on each side of the grate were then connected by cast iron tubes E, each forming a semicircular arch of 6 feet span, fastened into the sockets with well rammed iron cement. The cold blast was supplied to each of the ovens by a branch pipe taken direct off the large main from the blast engine, and entered the oven at the end furthest from the grate; it then passed through the arched

tubes E over the fire into the pipe D on the other side of the grate, and thence to the tuyere, leaving the oven at the end next the grate. Whilst the blast was traversing the two longitudinal pipes and the arched connecting tubes it received the direct heat from the grate, and was raised by this means to a temperature of 600° Fahr. The whole of the apparatus was enclosed in an arched oven, so as to retain and reverberate as much heat as possible. The general dimensions of the apparatus for each tuyere were as follows :—

Diameter of longitudinal mains at each side of grate	12 ins.
Length of ditto	10 ft.
Distance between ditto, centre to centre . .	6 ft.
Number of arched connecting tubes . . .	9
Internal diameter of ditto	4 ins.
External diameter of ditto	7 ins.
Height from grate to underside of arched tubes .	4 ft. 4 ins.
Area of heating surface per tuyere . . .	150 sq. ft.
Area of firegrate per tuyere	15 sq. ft.

On comparing this with the previous plan shown in Figs. 4 and 5, Plate 16, it will be observed that this apparatus, owing to its improved construction, maintained as efficient a temperature with less than two thirds of the heating surface per tuyere and little more than half the grate area. This oven was found to be a great improvement over the one previously described ; raising the temperature with less expenditure of fuel, less leakage, and greater regularity. It is evident that in this case the defects inseparable from the former plan were to a great extent remedied : for the new apparatus was constructed without any great continuous length of pipe exposed to the direct action of the heat ; the irregular action of the firing was materially diminished, each oven having its own independent grate ; and all flange joints were entirely excluded from within the oven.

The improved oven probably seemed perfect when first erected and set to work ; but after a short experience of its working objections were urged against it by the furnace managers on the grounds that, although the oven answered beautifully in respect of the temperature of blast produced, yet the socket joints would still sometimes leak, no matter how hard the cement was rammed in; that the arch tubes would crack over the grate ; and that, unless the stoker was very careful in

firing the oven, there was danger of burning the whole apparatus down when the fire was at all hastened, a case which happened once or twice. It was also objected that, owing to the proximity of the oven to the tuyere house, it was at all times more difficult to attend to the tuyeres; and that in the summer time the workmen so engaged, being hemmed in on one side by the hot ashes from the furnace on drawing the tuyere, and on the other by the oven, found themselves literally roasted. At the present day these difficulties might have been anticipated with such a construction of oven; but at the time must have been a source of great annoyance. Keeping in view however the points already gained in the arrangement of the oven, Mr. Neilson set to work to overcome the new difficulties thus brought to light, and produced an entirely new modification of the oven.

Up to this period the reference to the history of the hot blast oven has been confined entirely to what had been done by Mr. Neilson and his friends in Scotland; but as it now approaches the point where the experience of the Staffordshire district and that of Scotland unite, it may be well here to glance at what had been accomplished in this immediate neighbourhood up to the same time.

In the Staffordshire district a strong prejudice existed against pig iron manufactured with hot blast; and it was not until the hot blast had been in use some years in Scotland that it was taken up in Staffordshire. In 1834 Messrs. Lloyds Fosters and Co. of Wednesbury erected an apparatus at their works for heating the blast; and singularly enough at that early period proposed to apply the waste gases from the tunnel head for this purpose. This is believed to be the first attempt at utilising the waste heat in that portion of the furnace; and as such, is deserving of special notice. The apparatus constructed at these works consisted of a circular wrought iron heating chamber placed within the brickwork of the tunnel head, the flame from the furnace rising up through the centre of the chamber; the blast was supplied into it from the cold main through several small apertures, which distributed the air against the plates of the chamber on the side exposed to the action of the flame, and the hot blast was conveyed in a pipe down to the tuyeres. This apparatus

was very expensive in its first construction and constantly required repairs; and it produced a heat of only about 360° Fahr., so that a small supplementary oven was required near the tuyere to raise the temperature of the blast still further previous to its entrance into the furnace. It is almost unnecessary to add that this plan has long since been abandoned for more perfect arrangements.

About the same period Mr. Neilson's plan of hot blast was introduced by Messrs. Firmstone at the Lays Works near Dudley. The first experimental oven erected at these works was on the same plan as that last described as erected by Mr. Neilson, and shown in Figs. 6 and 7, Plate 17; "by which apparatus" Mr. Firmstone states "a supply of hot blast at 600° was with difficulty maintained, and never long without great damage to the semicircular arch pipes; and the pressure of the blast was seriously reduced by its friction in passing through the small arch pipes; but the effect in the reduction of the ores used was astonishing." To remedy these difficulties, both Mr. Neilson at Calder and elsewhere and Mr. Firmstone at the Lays proceeded to construct ovens on a plan similar to that shown in Figs. 8 and 9, Plate 17, which show the first permanent oven erected in 1833 at the Lays Works, and have been kindly furnished to the writer by Mr. G. Firmstone. In order to overcome the difficulty that had occurred previously from the arch tubes E being burnt down, they were elongated into the form of a syphon, in some instances carried to a height of 10 feet above the main; and as an additional safeguard the grate B was placed in a separate compartment, and the oven heated by the gases passing from the burning fuel through small apertures, as shown in Fig. 9. At this stage also the previous plan of having a separate oven to each tuyere was abandoned; and the general heating capacity was so much increased that one oven like that shown in Figs. 8 and 9 was found to be capable of heating the blast for three tuyeres to a temperature of 600° Fahr. The dimensions of the oven are as follows:—

Length of longitudinal mains	7 ft. 6 ins.
Number of syphon pipes	9
Area of direct heating surface, total	240 sq. ft.
Do. per tuyere	80 sq. ft.
Area of firegrate, total	9 sq. ft.
Do. per tuyere	3 sq. ft.

Fractures of pipes however and leakage of joints still took place, but to a much more limited extent than formerly; and these were found good ovens for the requirements of the furnaces of that period.

About this time there seems to have been great activity in designing ovens of different forms; for it was felt that the best form had not yet been devised, and there was much anxiety to obtain a wider experience of other forms. Amongst these may be noticed one form of continuous pipe oven, with horizontal pipes, shown in Figs. 10 and 11, Plate 18, and erected in 1836 at the Dowlais Works in South Wales: with a heating surface of 9 square feet the temperature of the blast was raised to about 300° Fahr. This oven is an improvement on the original continuous pipe oven shown in Figs. 4 and 5, Plate 16, as the expansion and contraction are better provided for; but it is far inferior to the last example, shown in Figs. 8 and 9, Plate 17.

Another form of continuous pipe oven, with vertical pipes, is shown in Figs. 12 and 13, Plate 18. It consists of a series of separate cast iron foot-boxes placed in the position of the longitudinal main on each side of the grate; each box was provided with two sockets cast on the upper side, excepting the boxes at each end of the oven which had only one socket, the other end of each terminal box communicating with the inlet or outlet pipe. Cast iron syphon pipes were then erected in the oven, each pipe footing in adjoining boxes; and the blast entering the oven at one end had to pass up and down alternately through the whole series of syphon pipes before leaving the oven at the other end. Ovens on this construction were erected at Ystalyfera and in North Staffordshire, that at Ystalyfera being heated by gases drawn from near the top of the furnace. This oven was an improvement on the arrangement shown in Figs. 10 and 11; the joints remained good, and the heat was well maintained; but the excessive friction of the long passage through the tubes greatly reduced the pressure of the blast, and this objection has prevented its extended adoption.

The best and simplest form of continuous pipe oven is the spiral one shown in Figs. 14 and 15, Plate 18, erected at the Ebbw Vale Works, South Wales, and heated by the waste gases. This oven consists of a continuous spiral pipe, was seldom out of repair, and maintained a good heat; but it involves, though in a lesser degree, the inherent

defect of all continuous pipe ovens, namely great loss of pressure in the blast in consequence of the friction occasioned by the whole of the blast having to travel at a rapid rate through one single pipe; and on this account it may be looked upon as retrograde in principle from the tubular arch oven introduced by Mr. Neilson.

Another arrangement of continuous pipe oven, with horizontal pipes, on a somewhat different principle, is shown in Figs. 16 and 17, Plate 18, erected in 1836 at the Codnor Park Works, Derbyshire. In this oven the cold blast entered through a small pipe A inserted within a larger one B directly exposed to the heat, and discharged itself at the far end of the smaller pipe into the large pipe, passing back along the annular space between the two pipes and becoming heated by contact with the outside pipe B; it was then collected again into a smaller pipe C inserted in the same manner into a larger pipe D below, and the same operation was repeated; the hot blast finally passing out at the end of the second large pipe D. This was not found to be a good form of oven: for, though ingenious, it will be observed that there are many flange joints within the oven; and the blast was subjected to a great amount of friction in its passage, almost more than in any other form of oven. Although one of these ovens was erected behind each tuyere, the heat maintained was much less than with the oven shown in Figs. 8 and 9, Plate 17, where there was only one oven to three tuyeres.

Another oven worthy of notice is shown in Figs. 18 and 19, Plate 18, erected at the Monkland Works near Airdrie. It consisted of two main vertical pipes EE of a horse-shoe pattern with numerous sockets cast on one face, erected opposite to each other at a distance of about 6 feet apart; small straight cast iron tubes F, 15 in number, were then inserted into the sockets, and the horse-shoe mains having been drawn together to close the sockets on the pipes, the joints were well rammed in with iron cement. This arrangement is interesting principally as giving the first example of the curved main; but as erected it was a comparative failure. It was subject also to the serious objection that, in the event of one pipe becoming burnt or damaged, either the sockets must be stopped up at each end, or the whole apparatus taken down to insert a single new pipe.

In addition to the above, a great number of other modifications of these principles were constructed at various works, involving different arrangements of the tubes and different modes of setting, too numerous to admit of notice in the present paper. It may be well to add however that, with a view of obviating the repeated fracture of pipes and joints, Mr. G. Firmstone made a further trial of wrought iron in the construction of ovens at the Lays Works, having the connecting arch pipes made of that material; but although this oven whilst in operation raised the temperature of the blast to 800° Fahr. and on this ground was declared by Mr. Neilson to be the most perfect apparatus he had then seen, the old defects of wrought iron in this position, arising from oxidation and want of durability as previously pointed out, soon became apparent, and the apparatus had to be abandoned.

With the increasing dimensions of the blast furnaces and greater consumption of blast, ovens of larger capacity now became necessary. To meet these requirements the first step was to place two ovens, on the principle of that shown in Figs. 8 and 9, Plate 17, either "end on" or "side by side," one against the other; the blast being conducted by means of a "stop" from the hot end of the first oven into the cold end of the second; and after traversing the latter it entered the furnace. This arrangement, called the double oven, was found to be a great improvement on the original single oven, materially increasing the uniformity of temperature of the blast, yet not involving a fully proportionate increase in the consumption of fuel. In some cases the same plan was further extended, as in Figs. 20 and 21, Plate 19, which show the ordinary Staffordshire long oven, first erected about 1837; this may be called a triple oven, having three compartments on the same principle as that in Figs. 8 and 9. Of the two modes of setting that called the "side by side" setting was perhaps the better, although generally the "end on" mode of setting was adopted, as shown in Fig. 20, Plate 19. In the "side by side" setting, all the flange joints were exposed outside the ovens and were therefore at once accessible for inspection and repair; and in addition all the firing holes were brought to one end of the oven. There

was a little more friction however in this case, from the blast having to traverse round a bend pipe in passing from the first to the second oven; whereas in the "end on" setting it passed direct into the main of the second compartment.

One great drawback however to all these ovens was found to be that, as a general rule, the liability to fracture increased in a much higher ratio than the mere arithmetical proportion between the number of pipes in the single oven and the number in the double or triple ovens. This may be partly accounted for by the increased temperature maintained towards the hot ends of these ovens, which always increases the liability to fracture; and partly by the much greater number of strains to which the joints and pipes were subject from the greater length of main and the corresponding irregularity of heating. It was further remarked that numerous fractures took place, especially at the hot end of the ovens, during the period of the morning and evening castings, when for the time the blast had been taken off the furnaces. For some time this fact was a great annoyance and its cause a mystery. However, by a careful consideration of the operations going on in the oven, both the cause of the annoyance and a remedy for it were discovered. It will be seen that, up to the period of casting, the blast was rapidly passing through the oven into the furnace, taking up from the inside of the pipes throughout its progress the heat slowly percolating through from the outside. On shutting off the blast any further abstraction of heat from the inside of the pipes by the passage of the blast ceased; and in consequence, although the damper of the oven might be closed down, which was not always attended to, a large unabsorbed accession of heat took place in the outer portion of the pipes. The numerous fractures were therefore with reason attributed to the sudden and irregular expansion occasioned in the pipes at that time; and the remedy, which being exceedingly simple was yet not discovered for some years, consisted in removing the escape valve of the blast engine from the cold to the hot end of the oven; by which alteration, whether the blast was on or shut off from the furnace, a regular current was maintained through the oven as long as the blast engine was at work. At the hot end of the oven a useful addition was also made by fixing a valve which opened inwards when the blast was shut off

from the oven or the blast engine was standing, thus forming a ready vent for the escape of any sulphurous or other gases, which occasionally during those periods are sucked in, and by their explosion frequently jar both joints and pipes.

The long oven shown in Figs. 20 and 21, Plate 19, consisted of 25 pipes, with 1200 square feet of heating surface, and 126 square feet of firegrate, and was capable of maintaining the blast for six tuyeres at a temperature of 600° Fahr. In general however ovens of this description could not be kept tight for any lengthened period, but required a thorough repair once or twice a year. These frequent repairs necessitated one improvement, till then generally overlooked, but of great practical value, especially where several ovens were at work behind a range of furnaces: namely the insertion of stop valves, one at the cold end and the other at the hot end of each oven, whereby that oven could at any time be completely isolated from the general range for repairs, without disconnecting any of the pipes. These valves were originally mere circular discs turned by a handle fixed on a centre spindle, similar to the old-fashioned throttle valve of a steam engine: subsequently, at the hot end of the oven especially, slide valves have been substituted; for with the great heat and pressure of a heavy blast the old disc valves used occasionally to stick or be blown out of shape and so become leaky; the slide valves answer admirably. These valves also give a ready and simple mode of testing the state of repair of each oven from time to time; for by shutting off each oven alternately and watching its effect on the speed of the engine, the leakage per oven can be observed with great exactness. In large works, without such a means of detection, leakages to the extent of 500 or 1000 cubic feet of blast per minute would frequently take place for months without any certain means of tracing them.

In reference to this construction of oven, in which the connecting tubes were in the form of long syphons, as shown in Figs. 8 and 21, it was further found that, independent of the failure of the socket joints due to the grinding action produced by the irregular expansion and contraction of the opposite longitudinal mains, a frequent fracture of the syphon pipes took place at the bend on the top side of the pipe.

This effect was ultimately recognised as arising simply from expansion, and may be readily explained by reference to the diagram Fig. 39, Plate 22, representing an ordinary syphon pipe when cold. If this pipe is heated up to a temperature of 600° or 800° with both legs free to follow their own inclination, it will assume the shape shown by the outer dotted lines. But if, instead of the two legs being allowed to move freely under the expanding influence of the heat, they be immoveably fixed down on each side to heavy cast iron pipes firmly bedded in brickwork, as in the oven under consideration and in all tubular ovens previously described, the pipe will assume the form shown by the inner dotted lines; and in its effort to assume the position naturally due to the expansion, a great tensile strain is exerted on the top side of the pipe at the bend, with a corresponding compression of the underside; and their combined influence results ultimately in fracture of the crown of the pipe from the top side.

The writer has not been able to ascertain to whom is due the merit of first introducing a practical remedy for this difficulty; but he is able to show, through the kindness of Messrs. Lloyds Fosters and Co., a drawing of one of the first ovens erected at their works about 1840, in which this difficulty was overcome. The oven is shown in Figs. 22 and 23, Plate 19; and as it presents many features of marked improvement over any of those previously described, it may be referred to more in detail. In all the previously described tubular ovens, the two legs of the pipes and the longitudinal mains were made as fast and immoveable as could be effected by cast iron and solid masonry. In the present example however one main C only was made fast, and even that was placed on cast iron saddles, to allow of a slight rotatory motion on its own axis; whilst under the saddles supporting the opposite main D cast iron rollers were inserted, which permitted the main to move freely under the influence of the expansion of the syphon pipes. This plan, by permitting the legs of the syphon pipes to assume their natural position under expansion, was found to be a great improvement, and fractures now seldom or never occurred from the strains which had previously proved so pernicious in the former ovens.

Up to this period the only means which the furnace manager had had of ascertaining whether the heat was being properly kept up was

by applying a small piece of lead to the stream of blast issuing from one of the plug holes attached to each tuyere: if the blast melted the lead the heat was considered up; if not it was considered down. This test however, involving a good deal of trouble, was frequently neglected; and in consequence the first intimation of the heat being down was seen when too late, by its effects on the working of the furnace shown by a change of cinder or the furnace slipping. In the present case however advantage was taken of the lateral oscillations of the loose main, which amounted at times to more than 2 inches, under the influence of variations of temperature, to construct a good practical pyrometer. This is shown at one side of the section of the improved Staffordshire oven in Fig. 22, Plate 19, and consisted of a simple bar fastened at one end to the loose main D, passing through the brick wall, and attached at the other end to a lever working a small index E. This answered the purpose very well; for the position of the index when the heat was sufficient to melt lead having been once ascertained, its position afterwards told at a glance the state of the oven. In some cases the movements of the loose main were communicated by a series of levers to the dampers; so that on the temperature rising beyond a certain point the expansion shut the dampers and prevented any further increase of heat, until the main had so far receded with the reduction of temperature as to open the dampers again.

In the ovens previously described the section of the syphon pipes was invariably circular, as shown in Figs. 33 and 34, Plate 22; the section Fig. 33, from the original Clyde oven shown in Fig. 6, Plate 17, was 4 inches internal diameter and 1½ inch thick; Fig. 34 is a section of the pipe in the Staffordshire long oven shown in Fig. 21, Plate 19, and was 5 inches inside diameter and 2 inches thick. In the improved Staffordshire oven however, shown in Fig. 22, Plate 19, the pipes were made of an oval section, 5 inches by 10 inches inside and 1½ inch thick, as shown in Fig. 35, Plate 22, whereby a very considerable increase of heating surface was obtained in proportion to the width of the pipes, without enlarging the casing of the oven or lengthening the mains. Some years previously to the more perfect development of this section as shown in the Staffordshire oven represented in Fig. 22, Plate 19, a somewhat similar section had been adopted by Mr. G.

Firmstone in the first experimental oven erected at the Lays Works as previously described, and was found to be an improvement; but the pipes being in the form of a semicircular arch with a radius of only 2 feet 6 inches, the underside of them was so near the grate that they were soon burnt down, and the elongated syphon pattern was found preferable. Mr. Firmstone has the merit however, as far as the writer is able to ascertain, of first adopting the oval section; which was thus subsequently revived in the oven shown in Fig. 22, and marked as decided an improvement over the other sections then used as his original oval section did over the small round-section arch pipes. The increased height to which the crown part was raised above the grate in Fig. 22, amounting to 11 feet 6 inches, enabled the pipes now to resist the fire, which in the first trial with the low semicircular arch had destroyed them and had thus probably led to the long discontinuance of the oval section. As a further precaution against the pipes being burnt, the legs of the syphon pipes in the oven shown in Fig. 22 were strengthened and protected at the point where the fire first caught them by a thicker strip of metal cast on at that part, as shown at AA.

The general dimensions of the improved Staffordshire oven shown in Figs. 22 and 23, Plate 19, are as follows:—

Length inside casing	16 ft.
Breadth ditto	7 ft. 6 ins.
Number of syphon pipes	16
Area of heating surface, total	700 sq. ft.
Do. per tuyere (four tuyeres)	175 sq. ft.
Area of firegrate, total	35 sq. ft.
Do. per tuyere	9 sq. ft.

An oven of these dimensions is sufficient to heat the blast for four tuyeres to a temperature of 600° or 700° Fahr.

Notwithstanding however the great improvements above described, which much diminished the number of fractures, these still took place; and, singularly enough, not now on the top side of the crown as before, but on the underside. This was accounted for by the fact that the strain in pushing out the loose main was comparatively easy to be borne, being distributed over the long bend of the top side of the crown; but the underside of the bend was of the weakest form for pulling back the heavy loose main on a reduction of

temperature, especially when the rollers had become clogged with an accumulation of indurated dust and clinker, as was frequently the case. A further reason also of this defect, and perhaps the more important one, was the circumstance that the iron at the underside of the bend, now subjected to tension, was exposed to the direct action of the heat, and therefore sooner lost its nature than the upper side of the pipe.

These considerations led to a further alteration in the form of the syphon pipe, as shown in Fig. 24, Plate 19; and at the same time the loose main was abandoned, notwithstanding its advantages as a pyrometer, and fixed mains were reverted to. The alteration in the syphon pipes consisted in having the two legs made vertical and parallel for some distance above the grate, instead of inclining towards each other; and connecting them at the top by a large semicircular arch. A flat oval section of pipe was employed, as shown in the section Fig. 36, Plate 22, though in some cases made a little wider at the back of the pipe than at the front next the fire. These pipes have been found to answer admirably: they are not apt to get burnt near the socket, as in the case of the overhanging syphon pipes previously described; nor are they apt to crack in any part of the semicircular arch, as the strain on expansion is distributed over such a length of circumference as to enable the metal to stand. The action of expansion will be readily seen from the diagram Fig. 40, Plate 22; and the ease with which this form of pipe is enabled to bear the strain, as compared with the previous syphon pattern in Fig. 39, is at once apparent.

A modification of this form of hot blast pipe was once tried, having the crown of the arch bent downwards in the middle, in the form of an inflected curve instead of a plain semicircular arch; but this proved an utter failure, the underhanging centre piece being quickly burnt down. It is mentioned here as a warning, in accordance with an observation which once fell from the first President of the Institution, the late Mr. George Stephenson: that nothing was of greater practical value than a record of failures.

Another form of oven constructed by the writer about three years ago and shown in Fig. 25, Plate 19, may be noticed before leaving the

consideration of the rectangular form of tubular oven. In this case the longitudinal main is cast in one piece, divided by a diaphragm in the centre, with double sockets on the top side for the syphons to foot in; it rests on a centre wall with the firegrates on either side. The form of the syphons is pear-shaped, and their section a flat oval. It is a double oven, set "end on," and the blast on entering the cold end proceeds along one half C of the first main as far as the stop in the centre, and passes over through the syphons into the other half D of the main, whence it proceeds into the second main, and passes over through the second set of syphons in the reverse direction. This oven raises a very good heat, but the pipes are apt to burn at the parts overhanging the grates on either side in the hottest portion of the oven next the middle wall. These parts are about to be strengthened and protected by strips cast on at AA; with the addition of a connecting web B between the feet of each syphon and cast with it.

Of the various ovens above described on the rectangular tubular construction the writer is inclined, after careful consideration of all circumstances, to give the preference to that shown in Fig. 24, Plate 19, in which the longitudinal mains are fixed and the syphons have their legs parallel and united by a large semicircular arch at the top. In leaving this portion of the subject the writer does not wish it to be supposed that he has noticed all the hot blast ovens which have been designed up to this period; but he has endeavoured to make such a selection as would enable the members to follow the various difficulties that have presented themselves with each class of oven, and to appreciate the painstaking perseverance with which during the last thirty years these difficulties have been encountered step by step and gradually overcome.

The description of oven now about to be considered is one the substantial advantages of which have gained for it during the last few years a wide reputation and increasing adoption. The arrangement is originally due, the writer believes, to the practical genius of Mr. Martin Baldwin, who first had an oven on this plan constructed at his works at Bilston, and by whose kindness the Institution is presented with a drawing of the first oven erected on this principle in 1851,

which is commonly known as the round oven, shown in Figs. 26 and 27, Plate 20. Bearing in mind the various defects which developed themselves more or less in all the ovens previously described, Mr. Baldwin directed his efforts—1st, to the construction of a main of such a form that its expansion or contraction should in no way tend to disturb the socket joints of the upright pipes; 2nd, to the construction of upright pipes that should have all the expansion they required without tending to disturb the socket joints or to break or burn down; 3rd, to the construction of a form of casing which, whilst it gave a good firegrate area, should be compact and as far as possible reverberatory, so as to throw back the heat on to the pipes and present as little surface as possible for its abstraction from the oven. In these points he succeeded to an extraordinary degree. It will be seen from the plan, Fig. 27, that the form of main designed was admirably adapted for the purposes in view; being circular or annular in plan, cast in two semicircular portions, with a longitudinal diaphragm through the centre dividing each portion into two compartments: on the upper side of each semicircular portion 24 socket holes were cast, 12 in each compartment, making 48 total. In the middle of the outer compartment of each main, between the sixth and seventh socket holes, a stop S was cast; and at either end of the main an inlet and outlet branch was cast on, communicating with the outer compartment. The two mains being placed on a brick foundation with firegrates below formed a complete circular main, ready for the insertion of the upright pipes. These consisted each of two straight pipes about 11 feet long, cast together, with spigot ends at the bottom fitting into the sockets on the main, and closed at the top with the exception of a lateral opening to permit one side of the pipe to communicate with the other. Each pipe was 4 inches inside diameter and 1½ inch thick, as shown enlarged in the section Fig. 37, Plate 22. Twenty-four of these pipes were fixed in the sockets on the mains, and the joints well rammed with iron cement; and a circular casing of masonry lined with firebrick was erected round them, and surmounted with an arched dome and stack. The cold blast, entering at the same end of each main through the inlet pipes placed side by side, traversed first the outside compartment of the mains as far as the stop S; and then passing up the

outer portion of the first six pipes and down the side next the fire it arrived at the inner compartment of the mains, from which it passed up the inner sides of the next six pipes and down their outer sides into the outer compartment of the mains beyond the stop, and thence issued through the outlet branches at the hot ends of the mains.

This oven was found to give a satisfactory heat, though not superior to that obtained with some of the other descriptions of ovens; but in freedom from fracture or leakage of joints it was soon found to be very greatly superior to any others. Since its first erection eight years ago no deviation from the principle of construction of the mains or pipes has been found necessary; the only alterations during that time having been the elongation of the legs of the main into a horse-shoe form in plan, and an increase in the diameter of the pipes with a diminution of their weight from about 1 ton to 16 cwt. each by reducing the thickness of metal. Nothing could stand better than the socket joints at the feet of the upright pipes; and the writer can state from personal experience that out of nearly 400 of these joints which have been within his daily inspection, and some of which have been made upwards of five years, not one has ever failed or had to be remade. The great durability of the socket joints and heating pipes arises from the two sockets in each pair being close together and cast in one piece, so that the distance between them is invariable and unaffected by expansion whatever be the temperature they are exposed to; while the pipes, being cast straight and without any points of contrary flexure, are not exposed to injury from the action of the fire, nor subjected to any strains from expansion, the whole of the expansion taking place vertically in the direction of the length of the pipe, as shown in the diagram Fig. 41, Plate 22.

In consequence of its complete freedom from fracture or leakage, attempts were early made to improve the mode of setting of this round oven, so as to obtain a larger heating power from it. One of the first defects observed was the position of the stack flue directly over the fire-grate, by which arrangement a large proportion of the column of heated flame and gases, instead of being distributed amongst and about the pipes, passed direct out at the stack without coming in contact with them. To obviate this difficulty in the next oven erected the hole

through the brick dome at the top communicating with the stack was built up, and the flues distributed round the outside casing of the oven at the top so as to create a draught from the grate to the back of the pipes all round. This was found to be a considerable improvement, but was to some extent counteracted by the casing of the oven being set back 14 or 15 inches from the pipes, in order to allow of back flues being taken under the mains from the grates, that some heat might ascend at the back as well as the front of the pipes: by this means a considerable amount of the reverberatory effect of the casing on the pipes was lost. It will be seen also that in the first form of round oven, shown in Figs. 26 and 27, Plate 20, a firedoor was placed at both the cold and hot ends of the grate: this was found to be very detrimental, especially in a high wind, as the comparatively free draught playing under the grate frequently blew the fire out at one door when blowing full in at the other, interfering seriously with the proper draught up the oven. These various defects were remedied by a further improved mode of setting, where the second firedoor is done away with, and the ash hole blocked up at that side; the brickwork is retained as at first close to the pipes, with only about 4 inches space; and the top flues are placed round the outside of the casing so as to distribute the heat as much as possible among the pipes, with considerable advantage in the increased heating power of the oven.

Figs. 28 and 29, Plate 20, show a further improvement of the round oven, representing one constructed in 1857 with an internal core C at the writer's suggestion by Messrs. Perry of Bilston for Messrs. Halloway's ironworks in the Forest of Dean. This arrangement has been found to be a valuable improvement, increasing the heating capacity of the round oven to the extent of one third with a smaller consumption of fuel. The advantages of a core consist in affording a greater amount of reverberatory surface; in making the temperature more uniform by absorbing any excess of heat and giving it out again on any diminution of temperature; and in occupying the large vacant space in the centre of the oven, thereby compelling a much larger amount of the heated gases to come into contact with the pipes. The area of firegrate in this oven is 38 square feet, and the area of direct heating surface in the pipes 850 square feet or 280 square feet per tuyere for three

tuyeres; it is capable of heating the blast for three tuyeres to a temperature of about 800° Fahr.

Shortly before this last form of round oven was erected, Mr. Josiah Smith of Dudley, who had paid great attention to the subject and to whom in a great measure the previous improvements in the setting of the round oven were due, finding that he required rather more heat than one round oven would afford and not wishing to go to the expense of erecting two, devised the plan of elongating the semicircular mains of the round ovens by the addition of a straight length of pipe at the extremities of each, thus forming an oval main and increasing the number of pipes from 24 to 32 in each oven, and at the same time affording a considerable additional space for the firegrate. This was found to be so great an improvement on the ordinary round oven that in the next one constructed the mains were further elongated so as to hold 18 pipes each or 36 per oven, with a proportionate increase of firegrate; at the same time a middle partition wall was built between the two mains, whereby the oven was divided into two distinct compartments so that one half could be cleaned out at any time without interfering with the other.

In the next example of oval oven the middle wall was overhung on each side by course over course being gathered over, thus forming a core, which was found to produce the same striking improvement as in the round oven before described. An oven on this construction with 56 square feet of grate area and 1350 square feet of direct heating surface is now heating the blast supplying seven tuyeres to a temperature of 800° Fahr. at the writer's works at the Parkfield Furnaces. Figs. 30, 31, and 32, Plate 21, show a further example of this mode of construction in the case of an oval oven with core having 40 pipes, erected by the writer in 1858 at Parkfield, in which the area of firegrate is 54 square feet and the area of direct heating surface in the pipes 1500 square feet or 250 square feet per tuyere for six tuyeres. The present number of tuyeres supplied by this oven however does not represent its full capacity, as it is capable of supplying ten tuyeres if pushed a little in the firing. The success of ovens of this description depends to a great extent upon good workmanship, upon all the parts

being well and thoroughly put together. The ovens above described have been erected principally by Mr. Andrew Woodhouse of Dudley; and a great amount of credit is due to his practical skill and attention to all points of detail in any degree likely to affect the economical working of the oven, especially as regards the proper adjustment of the flues.

In order to cleanse the oven without having to shut the blast off, small cast iron box frames with doors have been inserted in the brickwork at D, Figs. 30 and 31, Plate 20, opposite each of the top flues; by which means access is given to one at a time, and they can be cleaned out all in succession in a few hours without interfering in any way with the working of the oven. The dust removed in cleaning these flues would to some extent fall down in between the upright pipes and behind the main pipe. To cleanse these parts of the oven small box frames are inserted at E, Figs. 31 and 32, Plate 21, opposite each space between the pipes and near the socket joints, so that all rubbish or dirt which might accumulate between the pipes can be removed; and similar cleansing holes placed behind the main at F enable the process of cleaning to be completed. Though this might be considered a minor point, it is really one of considerable importance in an oven such as that now described; for in consequence of the entire freedom from liability to fracture or leakage, the oven can thus be kept continuously at work for many years without the necessity for the blast being once taken off for cleaning out the oven.

Since the construction of the elongated oval oven above mentioned, a further extension of the horse-shoe plan has been adopted, so as to contain 44 pipes per oven; and in order to strengthen the overhanging core wall by the addition of more material in the centre, the sides of the horse-shoe instead of being made parallel as hitherto are made slightly diverging at the heels, making the width of the oven greater at the centre than previously. In some recently erected ovens Chanter's shifting grate bars have been used with advantage.

From a consideration of all the circumstances and requirements of a good hot blast oven, those constructed as shown in Figs. 28 and 31, Plates 20 and 21, appear to the writer to be far superior to any other. The best oven is that which for the longest period without leakage

will heat the greatest amount of blast to the highest temperature with the smallest consumption of the cheapest fuel; and in all these respects the round or oval ovens with internal cores are to be preferred.

As regards the sections of the hot blast pipes, these have undergone great modifications during the last thirty years, especially in the thickness of metal, as shown in the sections Figs. 33 to 38, Plate 22. The thickness has increased gradually with the diameter and height of the pipe, from 1½ inch in the earlier examples to 2 and 2½ inches in some cases, with the idea of preventing breakage; but as the laws affecting the expansion and contraction of the metal became better understood and allowed for, the thickness was reduced to 1½ inch, and finally in the present upright pipe of the round and oval ovens to about 1 inch thickness of metal, as shown in the section Fig. 38, which is the section now preferred. Thus a considerable saving has been effected, not only by reduction in the weight of the pipes, but by their more rapid absorption and transmission of the heat, which is inversely as the thickness of metal.

An almost indispensable adjunct to these or any other ovens is an efficient and simple pyrometer, such as Gauntlett's, which the writer has had in constant use for some months. This consists of a simple and ingenious method of measuring the variation of temperature by the differential expansion of two metal tubes or rods, one end of which is inserted within the hot blast pipe leading from the oven, while the other gives motion to a small finger working round a dial plate. It is set to work up to 1000° Fahr., and although it may not be exactly accurate as compared with a standard gauge, yet it has the advantage of being always correct with itself; and the furnace manager having once ascertained the point the finger must arrive at for lead to be melted can see at a glance in future whether the heat is above or below the proper degree.

In regard to the economical consumption of fuel, it is difficult to compare one oven with another, whether they be of nearly similar construction, or whether built on different principles but of nearly the same heating capacity. The difficulty arises from the differences in the construction, burden, and working of the furnaces to which the ovens

are applied; and also from the differences in the temperature of blast, the quality of slack used for the oven, and the care of the stoker: all of which, independent of the construction of the oven, must more or less affect the yield, that is the quantity of slack consumed by the oven per ton of iron produced from the furnace. It is also a mistake to look to the consumption of fuel alone as a test of the efficiency of a hot blast oven: as it is quite possible for one oven consuming 6 cwts. of slack per ton of iron to be a more economical one than another consuming only 5 cwts. per ton; the blast in the first case being kept more uniformly at a higher temperature and the furnace yield perhaps showing several cwts. of coal per ton of iron in its favour. There is no doubt however of a very great saving having been effected during the last thirty years in this respect. As far as can be gathered from early statements, 8 or 10 cwts. of slack per ton of iron were at first required to heat the blast to 320° Fahr.; while at present, with a consumption of 5 cwts. of slack per ton of iron, it is not at all uncommon to secure a blast uniformly heated to 800° Fahr. Thus the successive experiments on the construction of the ovens have resulted in the same quantity of slack being now made to perform from four to five times its original work. At the writer's works the consumption of slack for heating the blast to the temperature of 800° Fahr. has been reduced since the introduction of the oval ovens to 4½ cwts. per ton of iron made, as compared with between 8 and 9 cwts. used previously for raising the blast to a temperature of only 600°.

In concluding this paper the writer has to thank many friends, and others with whom he has not the pleasure of personal acquaintance, for the very liberal spirit in which both drawings and information have been furnished to him for the purpose of the present paper. The subject is one which has had a vast influence for many years on the interests of the iron trade, and through it on the country and the world at large; but it is even more interesting as exemplifying the patient persevering efforts, whereby difficulties that appeared insurmountable have been overcome, the contending forces of nature have been balanced and controlled, and at the same time increased efficiency, economy, and durability have been achieved.

The CHAIRMAN considered they were greatly indebted to Mr. Marten for his able and valuable paper, and the trouble he had taken in collecting such complete information on the subject, and also for preparing the extensive series of drawings.

Mr. MARTEN said he had had great pleasure in collecting the information contained in the paper for permanent record in the proceedings of the Institution; it would serve to show in future years the progress of the invention up to the present time, and would also be useful in drawing attention to the difficulties to be encountered in any further improvements that might be attempted. The subject was one of great interest in that neighbourhood, from the influence of hot blast upon the economy of manufacture of iron, as well as from the great amount of ingenuity and perseverance shown in carrying out the successive improvements in its application. He was much indebted to the assistance of the Secretary in preparing the paper and drawings; and he had great pleasure in acknowledging the liberal spirit in which he had been supplied with information by the different parties who had effected improvements in the ovens.

Mr. SAMPSON LLOYD, having been connected with the first introduction of hot blast into Staffordshire and the earliest manufacture of hot-blast iron in that district, had witnessed the whole progress of the invention from the commencement, and thought the paper just read gave a comprehensive account of the successive improvements that had taken place; it also pointed out in a clear and useful manner the difficulties that had been met with, and the causes from which they arose. There was an almost inconceivable prejudice at first against the use of hot blast in iron furnaces, so much so that it was at first nearly impossible to sell a single pig of hot-blast iron, and several years elapsed before the consumption of hot-blast iron was anything to be mentioned; whilst at the present time the hot blast was almost universally adopted wherever iron was made.

The mode of heating the blast first employed at his own works at Wednesbury was Mr. Neilson's early plan of long air mains lying in the heating flues as described in the paper, and a great advantage was at once found in the use of hot blast, by diminished consumption of fuel in the iron furnace; but the trouble and defects experienced with

this early form of the apparatus were very great indeed. Mr. Firmstone next took up the subject actively, and made an important improvement in the ovens by the adoption of syphon pipes, as described in the paper; and other ironmasters in the district gradually joined in adopting the hot blast, and ultimately succeeded in fairly introducing its use into Staffordshire. The plan of leaving the main pipe loose on one side of the oven he remembered first seeing at Mr. Henry Williams' works at Westbromwich, but did not know where it originated; the loose main working on rollers was found to be a great improvement, as also was the addition of ball and socket joints at both ends of the mains, to allow of the slight rotary motion caused by the lateral movement of the arched pipes in expansion; a great deal of the trouble arising from leakage and fracture of the pipes was thus saved, and he continued to the present time to use ovens on this construction without difficulty or inconvenience and with satisfactory results in working. He had also one of the early round ovens at work, but the heat raised by it was not nearly equal to that obtained with the rectangular oven, on account of the inferiority in the mode of setting and the large vacant space in the centre of the oven over the fire. He had not yet tried any of the ovens with firebrick cores in the centre, but the cores would certainly prove of much benefit in round and oval ovens, by filling up the vacant space and bringing the heat from the fire in closer contact with the heating pipes, and at the same time preventing fluctuations in the temperature of the blast by equalising the heat of the oven. Although such great progress had been already made in the mode of heating the blast, there were no doubt many improvements of importance still to be effected in the construction of the ovens.

Mr. G. A. Everitt asked how long an interval there was between the first trial of hot blast by Mr. Neilson in Scotland and the introduction of the plan into Staffordshire.

Mr. Sampson Lloyd replied that the first use of hot blast by Mr. Neilson in Scotland was in 1829, and it was introduced into Staffordshire in 1832. A remarkable circumstance was that at that time the ordinary make of iron was only about 50 to 60 tons per week from each furnace, which was considered a good yield; but at the

present time, with the extended use of hot blast, the yield was increased to upwards of 200 tons per week from the same sized furnaces, thus showing the enormous increase of production effected with the same outlay of capital by the employment of hot blast and other improvements in the furnaces.

Mr. W. Smith thought the paper that had been read was one of much interest, giving a valuable historical account of the successive steps in practically carrying out the system of hot blast; and the large increase in yield of the furnaces that had been referred to marked the introduction of the hot blast as a step of the greatest importance. The prejudice against the use of hot-blast iron was however still entertained; and he had noticed, in a recently published report on marine engines for the navy by the government commissioners, a recommendation that hot-blast iron should not be used in their construction, which was a conclusion much at variance he thought with the results of general experience in the use of best hot-blast iron: it was a question of the quality of the ore from which the iron was made and the care in its manufacture, rather than a question of hot or of cold blast.

The Chairman thought the whole question involved in that report was a very important one; and as the results arrived at would not be generally agreed with it would be well if the members interested in the subject would take it into consideration, and it might be brought under discussion with advantage at a future time.

Mr. Sampson Lloyd observed that the chemical effect of the hot blast in the iron furnace and the quality of the material produced by its use was an entirely different question from the method of heating the blast; the former question might perhaps be the more important of the two, but the paper had reference only to the mode of heating the blast and the increased yield of the furnace, without regard to the quality of the material produced, which was an independent consideration and had given rise to some diversity of opinion.

Mr. Marten thought the prejudice that existed against the hot blast had arisen chiefly from the facility it afforded for using inferior materials in the blast furnace, which of course could produce only an inferior quality of iron; but he believed that from equally good

materials hot-blast iron was found to be little if at all inferior to cold-blast.

In the construction of rectangular ovens having a loose main, the addition of the cup and ball joints at the ends of the mains was a decided improvement, by providing for the slight rotary motion of the mains under expansion, which would break any joints if not allowed for. He fully realised the difficulty experienced with the early form of round oven, to which reference had been made, in consequence of its deficiency of heating power: the first round ovens that he had at his own works were found to be inferior to the rectangular ovens except in freedom from leakage and fracture of the pipes, in which respect they were greatly superior. He then became satisfied that the round oven was superior in principle, as the leakage and fracture of the pipes were the most serious defects that had to be contended with; but the ovens required improvement in the details of setting. The improvements subsequently made in this respect had entirely removed the objections previously experienced; and the round ovens were now found so superior in regularity and economy of working as well as in freedom from leakage that the whole of the long rectangular ovens at his own works had been taken down and replaced by round and oval ovens, with the exception of one oven having a single longitudinal main and pear-shaped syphon pipes on the construction described in the paper, which would also be removed when requiring serious repair. The chief advantage however of the round and oval ovens arose from the firebrick core in the centre, which produced an extraordinary degree of regularity in the heat of the blast; for the pyrometer showed that the temperature did not vary more that 50° above or below a mean temperature of about 800° Fahr.

Mr. Samuel Lloyd hoped a supplementary paper would be given by Mr. Marten or some other member on the extension of the use of hot blast, and improvements in the manufacture of hot-blast iron, for the purpose of introducing that branch of the subject.

The Chairman proposed that the discussion should be adjourned to the next meeting to afford an opportunity for further consideration of this important subject, when he hoped the further paper on the subject of hot-blast iron would be given as suggested. He proposed

a vote of thanks to Mr. Marten for his paper, which was passed.

Mr. Marten said he should be happy to render every aid in the matter, and hoped it would be taken up by some other member.

The following Paper was then read, communicated by the Chairman, who remarked that, as the writer was not himself a member of the Institution, he had introduced the paper for him, to enable him to bring the subject under the consideration of the members, but the paper was entirely Mr. Jensen's :—

ON A MARINE ENGINE GOVERNOR.

BY MR. PETER JENSEN, OF COPENHAGEN.

The engines in very large screw steamers with deep draught are considered to work with sufficient regularity even in a gale, as the size and weight of the ship to a great extent prevent it from pitching; and for this reason no great difference in the depth of immersion of the screw takes place: but, except in the above case, serious irregularity is experienced in the working of marine engines in a heavy sea, when the screw or the paddle wheels are one moment deeply immersed and the next moment revolving half or more in the air. A waste of power then occurs; for although in a given time the same amount of power is supplied from the boiler, whatever the speed of the engines may be at any moment, still the power is not exerted in an advantageous manner whenever the propeller is only partially immersed, as it then presents too little surface of resistance to the water, and is consequently not able to propel the vessel so efficiently as when immersed to the proper depth. In most marine engines therefore, instead of the consumption of steam being reduced by saving the steam when it cannot be used to advantage in consequence of the propeller being only partially immersed, it is at that time wasted in driving the screw or the paddle wheels with great speed in a light draught of water, and a great amount of slip or loss in effective speed of the vessel consequently ensues. In applying a governor to marine engines economy of power must result, as in the case of stationary engines. Moreover most of the accidents occurring to marine engines are due to the sudden shocks that will happen during a gale even in well balanced engines. The lubrication is also often rendered difficult, because the oil is thrown out of the cups; and the great amount of wear and tear in marine engines may be attributed partly to the shocks and the irregular motion, and partly to the more imperfect lubrication.

Marine engine governors have been attempted on several occasions, but only very few are yet applied. An ingenious modification of the ordinary Watt's centrifugal governor has been employed for this purpose, Silver's four-ball governor, in which the action of a spiral spring is substituted for that of gravity, and the whole apparatus is balanced so as to remain undisturbed in action during the pitching of the vessel. But the mode of action of all such governors is by checking the supply of steam to control the speed of the engine *after* it has begun to change either to quicker or slower: and it has appeared to the inventor of the governor forming the subject of the present paper, that the principal desideratum in a good marine engine governor is an instantaneous action, so that whenever the screw or the paddle wheels are going down in the water more steam may be admitted to the engines as quickly as possible, and in the opposite case the admission of steam may be as quickly as possible checked, *before* the speed of the engines has been sensibly affected. For attaining this object it seems more natural to make use of the cause of the evil as a remedy against it, or to employ the irregular motion of the vessel as a means of regulating the engines, than to let the engines regulate themselves. By this means an intermediate step is dispensed with; and by making use of the non-elastic water as the motive power of the governor, the action will be exerted quickly enough upon the engines to regulate the supply of steam before the depth of immersion of the propeller has been materially altered by the pitching of the vessel.

The construction of the new Marine Engine Governor is shown in Plate 23, in which Fig. 1 is a transverse section of the vessel showing the governor in position; and Figs. 2 and 3 are a longitudinal section and elevation of the governor enlarged.

A cylinder A is placed at each inner side of the vessel below the water line, the bottom of the cylinders communicating with the water outside by means of the Kingston valves B. Each cylinder is fitted with a piston C, which is loaded with a spring D either of steel, compressed air, or india-rubber. The piston rods E act upon bell crank levers FF, and by means of connecting rods GG motion is given to a common spindle H, from which the throttle valves of the engines

are worked in such a manner that when the pistons C go down the throttle valves are closing, and when the pistons go up the valves are opening. Now as the pressure of the external water increases in proportion to the depth, when the openings of the valves B come into different depths in consequence of the pitching or rolling of the vessel, the pressure on the pistons C will be changed proportionately; and to each pressure will correspond a certain position of the pistons and of the throttle valves connected with them. Omitting the pitching of the vessel in a paddle wheel steamer and considering only the rolling motion, it is obvious that when one paddle wheel is deeply immersed and the other nearly or entirely out of the water, the pressure on the two pistons will be different; but supposing them connected together, the position of both and of the throttle valves will be then corresponding to the difference of resistance on the two paddle wheels.

If these cylinders are placed as near to the propeller as convenient, so as to ensure pretty nearly the same depth of immersion, it will be seen that this apparatus will then act as a governor for the engines: for when the propeller is revolving in a light draught of water, the supply of steam to the engines is proportionately diminished; and when revolving in deep water, the supply of steam is proportionately increased. The whole arrangement is simple, as shown by the drawing, and the cost small, probably not exceeding 4 or 5 shillings per horse power.

Mr. W. Smith thought it was very desirable for attention to be drawn to the great importance of having such a governor generally employed in marine engines for controlling the speed of the engine in rough weather; he considered an efficient governor was even more necessary for marine engines than for land engines, for not only were marine engines subject to more sudden shocks, but there were abundant facilities for repair on land, whilst at sea any accident to the machinery was of much more serious consequence, involving the risk of disabling

the vessel. He thought the governor described would be very serviceable if properly applied and in the best situation. He remembered a somewhat similar plan of governor being proposed when the screw propeller was first becoming generally adopted, the governor acting when the stern of the vessel became exposed; but it was not meant to be applied to paddle wheel steamers, as it was considered that when one paddle wheel was out of the water the other would be fully immersed, and the power absorbed from the engine would remain the same. Another governor had also been recently designed for the same purpose, similar in many respects to the one now described, consisting of a long vertical cylinder fixed in the after part of the vessel near the propeller, having the piston connected to the throttle valve by levers and adjusted to the draught of water, with springs to give a quicker action; and for paddle wheel steamers two of these cylinders were proposed to be employed and to act separately on the throttle valve. He understood this governor had been tried in one of the Glasgow and Philadelphia steamers; but it did not appear to have been very successful in working, and had therefore been removed.

The Chairman remarked that the governor described in the paper belonged to the class of "storm" governors, for controlling the engine in a rough sea; such a governor was not required in still weather, when the work upon the engine was nearly uniform, as the ordinary governor was then sufficient for regulating the speed; but a separate special governor might be desirable in stormy weather to avoid the objectionable necessity of a man standing by the throttle valve to ease the engine instantly when beginning to run off. Several plans had been proposed for that purpose at different times, in one of which a pendulum weight was employed in connexion with the throttle valve, to regulate the admission of steam according to the rolling motion of the vessel.

Mr. Jensen said he had long had this plan of governor under consideration, and on coming over to England expected to find some such contrivance already in use for regulating the speed of the engine in stormy weather; but on making enquiries on the subject he could not learn that such a governor had ever been tried, and was therefore induced to bring it forward, as something of the kind was evidently much needed in a rough sea. He enquired why the governor that had

been referred to on the Glasgow and Philadelphia steamer had been abandoned, and what were the results of its working.

Mr. W. Smith replied that he did not know the particulars of its working, and was not aware why it had been abandoned.

The Chairman proposed a vote of thanks to Mr. Jensen for his paper, which was passed.

The Meeting then terminated.

PROCEEDINGS.

July 27, 1859.

The General Meeting of the Members was held at the house of the Institution, Newhall Street, Birmingham, on Wednesday, 27th July, 1859; Joseph Whitworth, Esq., Vice-President, in the Chair.

The Minutes of the last General Meeting were read and confirmed.

The Chairman announced that the Ballot Papers had been opened by the Committee appointed for the purpose, and the following New Members were duly elected :—

MEMBERS.

George Alton, ...	Derby.
John Butler, ...	Leeds.
Thomas Wilks Lord, ...	Leeds.
Joseph Pitts, ...	Leeds.
Thomas Swingler, ...	Derby.
George Taylor, Jun., ...	Leeds.

An abstract was then read of the Paper read at the previous meeting, "On the construction of Hot Blast Ovens for Iron Furnaces," by Mr. Henry Marten, of Wolverhampton, (Proceedings, May, 1859,) the discussion of which was then continued.

Mr. H. Maudslay observed that at the previous meeting the subject of the paper was considered so important that it was thought desirable for the discussion of it to be adjourned, in order that it might be continued at the present meeting and might include also the further subject of the relative quality of hot-blast iron as compared with cold-blast; for the great advantages that had arisen from the introduction of the hot blast in the manufacture of iron and the great addition it had caused to the quantity of iron manufactured in the country made this subject one of wide interest. They were much indebted to Mr. Marten for the complete information contained in his paper, giving so interesting and valuable an account of the gradual rise and progress of the invention up to the present time, and for the extensive series of drawings by which it was accompanied. He was very glad they had the advantage on the present occasion of the presence of Mr. Neilson, the inventor of the hot blast; and hoped he would give them an explanation of the circumstances that first led him to the idea of the hot blast.

Mr. Neilson said it was easy to explain how he had first thought of heating the blast: much easier than to explain fully the results obtained by the hot blast. Six or seven years before he brought out the plan, he had read a paper before the Glasgow Philosophical Society on the best mode of taking out the moisture from the atmospheric air in summer time, previous to its entrance into the furnace through the tuyeres; for it was found that the make of iron was much impaired in summer weather both in quality and quantity, and he had become satisfied that the cause lay in the greater proportion of moisture contained in the air at that season. His first idea was to pass the air through two long tunnels containing calcined lime, so as to dry it thoroughly on its way to the blast cylinder of the blowing engine; but this plan was not put to trial. About that time his advice was asked by a friend, Mr. James Ewing of the Muirkirk Iron Works, in regard to a blast furnace situated at a distance of half a mile from the blowing engine, which did not obtain a sufficient supply of blast at that distance, and consequently did not make so much iron as two similar furnaces situated close by the same engine; and it then occurred to him that since air increases in volume according

to its temperature, if it were passed through a red-hot vessel before entering the distant furnace its volume would be increased and it might be enabled to do more duty in the distant furnace. Being at that time engaged in the Glasgow gas works he made an experiment at once on the effect produced upon the illuminating power of gas by a supply of heated air brought up by a tube close to the gas burner; and found that by this means the combustion of the gas was rendered more perfect and intense, so that the illuminating power of the particles of carbon in the gas was greatly augmented. He then tried a similar experiment with a common smith's fire, by blowing the fire with heated air; the effect was that the fire was rendered most brilliant, with an intense degree of heat, while another fire blown with cold air showed only the brightness ordinarily seen with a high heat. Having obtained such marked results in these small experiments it then occurred to him that a similar increase in intensity of combustion and temperature produced would attend the application of the same plan on a large scale to the blast furnace; but his great difficulty in further developing the idea was that he was only a gas maker, and could not persuade ironmasters to allow him to make the necessary experiments with blast furnaces at work. At that time there was great need of improvement in the working of blast furnaces, for many furnaces were at a stand for want of blast, being unable to maintain the necessary heat for smelting the iron; and unless as much as £6 per ton could be obtained for the iron no profit was realised, on account of the heavy expenses attending the furnaces. A strong prejudice was felt against any meddling with the furnace, and a kind of superstitious dread of any change prevailed, from the great ignorance of furnace managers with respect to the real action going on in the furnace and the causes of the fluctuations that occurred; when a furnace was making No. 1 iron no one would be allowed to touch it, for fear that if any change took place it might be many weeks before the furnace got round again from white iron. He at length succeeded however in inducing Mr. Charles MacIntosh of Glasgow and Mr. Colin Dunlop of the Clyde Iron Works to allow him an opportunity of trying the application of heated air for blowing a furnace; and though the temperature of the air was raised but little, not more than about 50° Fahr., he was glad to be allowed to

make a trial even with so small an amount of heat. This first imperfect trial of hot blast however, with a rise of temperature of only 50°, showed a marked difference in the scoria from the furnace, causing it to be less black or containing less iron; and he was therefore anxious to try the plan on a more extensive scale, in order to satisfy himself as to the change in the make of iron and to establish the correctness of the principle. He was still retarded by the strong objections of ironmasters to any alterations in connexion with the furnaces, which prevented him from making the necessary experiments for ascertaining the best way of carrying out the plan: in one instance where he had so far succeeded as to be allowed to heat the blast main, he asked permission to introduce deflecting plates in the main or to put a bend in the pipe, so as to bring the blast more closely against the heated sides of the pipe and also increase the area of heating surface, in order to raise the temperature to a higher point; but this was refused, and it was said that if even a bend were put in the pipe the furnace would stop working. These prejudices proved a serious difficulty, and it was two or three years before he was allowed to put a bend in the blast main; but after many years of perseverance at the subject he was at length enabled to work out the plan into a definite shape at the Clyde Iron Works, as had been so completely and correctly described in the paper that had been read.

The invention of the hot blast consisted solely in the principle of heating the blast between the engine and the furnace, and was not associated with any particular construction of the intermediate heating apparatus; this was the cause of the success that had attended the invention, and in this respect the case had much similarity to that of his countryman James Watt, who in connexion with the steam engine invented the plan of condensing the steam in a separate vessel, and was successful in maintaining his invention by not limiting it to any particular construction of condenser. He was glad of this opportunity of acknowledging how firmly the English ironmasters stood by him in the attempts made in the early time of the use of hot blast to deprive him of the benefits of his invention; and to them he was indebted for the successful issue of the severe contest he had then to go through.

Mr. Marten thought the information given by Mr. Neilson was of a most interesting character, and it was a great advantage to have had the opportunity of hearing the particulars of the patient perseverance displayed by him in carrying out the important invention of the hot blast; his example was a great encouragement to others to meet the difficulties they must encounter in prosecuting any new idea to a successful result. In the hands of any one less persevering and indefatigable the idea of the hot blast might have been tried for a few months only and then abandoned, and the results would have been lost to the world, or left to be worked out by others who would then have derived the benefit of the original invention.

At the previous meeting reference had been made to a part of the recent report * of the committee appointed by government upon the marine engines for the navy, in which it was recommended that the use of hot-blast iron should be entirely excluded in their construction; and he considered it right that this extraordinary conclusion should be further noticed. It appeared from the report that the committee witnessed a trial of the comparative strength of a pig of hot-blast iron and another of cold-blast, in which the hot-blast pig was broken by a single blow of a small sledge hammer, while the cold-blast stood repeated blows of a very large sledge hammer before it broke; also the hot-blast pig was broken by being thrown upon the ground, while the cold-blast bore the fall without injury. No other experiments were mentioned, and the committee proceeded to recommend the entire exclusion of hot-blast iron in the construction of marine engines for the navy, and he was greatly surprised at such a strong opinion being expressed upon such inadequate data; the experiment described was a very unsatisfactory mode of ascertaining the relative qualities of hot and cold-blast iron, and not sufficient to afford any ground whatever for so serious a conclusion: for it was evident that the comparison had been made between a good cold-blast pig, and a hot-blast "cinder pig," which being made of very inferior materials was far removed in quality from the first class of hot-blast pig iron. It was important

* Report to the Lords Commissioners of the Admiralty by the Committee on Marine Engines, with Replies by the Surveyor of the Navy. 4th April, 1859. Page 30.

that the mistaken views advanced in the report should be discussed and set right, as the question was one closely affecting the ironmasters and also the country at large; for if the quality of hot-blast iron was as good as that of cold-blast and its cost only half that of the latter, a great waste would be occasioned if cold-blast iron were to be used throughout the machinery for the navy where hot-blast would answer quite as well and at half the cost. Fortunately however the Surveyor of the Navy's replies were printed throughout with the report, and were of much value in correcting the erroneous views advanced: and it was there pointed out, in reply to the suggested exclusion of hot-blast iron, that there is no ground for prohibiting its use, simply because it is cheap and may be improperly used; since it is unquestionably productive of benefit, when used with judgment.

This portion of the report showed a great ignorance of practical ironmaking, the only difference recognised in the qualities of the two descriptions of iron being that due to the temperature of the blast; and the experiment witnessed was unsatisfactory and inconclusive, a single pig of iron only being dealt with in each case, and no mention being made of the locality of production, or the quality of the pig as regarded the material from which it was made. There were three principal classes of pig iron: namely cold-blast mine iron, in which the material used was entirely mineral or ironstone from the mine, smelted by cold blast; hot-blast mine iron, made from the same material by hot blast; and hot-blast cinder iron, made from inferior materials and from the cinder of puddling furnaces mixed in the blast furnace. The quality of each description of iron was due almost exclusively to the materials, that is the ironstones, fuels, and fluxes, used in the furnace for its production, and varied continually even at the same works according to the nature of these materials. The ironstones varied greatly in quality, and there were altogether more than 150 different varieties now known, which might be classed into the following eight principal divisions:—

1.—*Black Band* ironstone of Scotland. This is the principal ironstone of Scotland: when smelted with cold blast it produces an inferior iron, and indeed as a cold-blast iron can hardly be made, since with the generally inferior fuel there obtained the necessary heat for smelting is with difficulty maintained with cold blast, and the furnaces are consequently liable to serious fluctuations in working: the cold-blast iron of Scotland is scarcely in any instance superior to the hot-blast of that country. When made by hot blast the iron produced is of a useful quality for foundry purposes, though not very tough.

2.—*Hematite* ironstone of Cumberland; produces either with hot or cold blast a very strong tough pig, forming a good iron either for forge or melting purposes, but red-short. It is very good as a toughening mixture.

3.—*Cleveland* ironstone of Yorkshire. This is a different and peculiar quality of ironstone, only recently worked, but the iron made from it is now largely exported and also used extensively in this country. With hot blast it produces a serviceable but rather cold-short iron, and a fair quality for castings or forge purposes. The ironstone of this district is invariably smelted by hot blast.

4.—*Clay Band* ironstone of Derbyshire, Staffordshire, and Shropshire; produces a good tough iron with either hot or cold blast, and when judiciously mixed in the furnace a fine quality of pig is obtained for best and general purposes.

5.—*Hydrate* ironstones of the Churnet Valley; these give a very fine soft iron with either hot or cold blast.

6.—*Northamptonshire* ironstone. At first a very inferior description of iron was obtained from this ore; but now with a better management of the furnace specially adapted to this ore, and good fuel, a very soft and fluid quality of melting iron is produced with hot blast, which compares well with the general average.

7.—*South Wales* clay band ironstone; produces fine descriptions of pig iron with either hot or cold blast. The South Wales ironworks are chiefly dependent for their iron making on the excellent quality of fuel obtained there, and the mixtures of ores used in the furnaces are largely imported from surrounding districts.

8.—*Forest of Dean* ironstone; produces with either hot or cold blast a very fine description of pig iron.

It thus appeared that many of the ironstones made a good quality of iron both with hot and cold blast; the largest portion of the iron in the country, more than 90 per cent. of the whole, was now made by hot blast, and in many cases the iron was within a trifling percentage of the same strength as cold-blast iron. The bad name at

first acquired by hot-blast iron arose from not distinguishing between mine and cinder iron, and from the facility afforded by the hot blast for making iron from very inferior materials, such as flue and tap cinder and the refuse scale of the mills and forges, which could not be worked at all by cold blast, and of course could produce only an inferior quality of iron. The best class of cold-blast iron was no doubt somewhat superior to the best hot-blast, as a rule; but the difference was not so marked as to warrant any unqualified condemnation of hot-blast, such as was conveyed in the report that had been referred to, or by any means to justify its exclusion from first class mechanical purposes, where judiciously used: for hot-blast iron, especially in second runs and for foundry purposes generally, was an excellent material when made from good ores, and the great bulk of best hot-blast castings made from judicious mixtures were quite equal to those of cold-blast iron, and at the same time much cheaper.

Notice of the opinion expressed in the report was probably more particularly desirable for abroad than for this country, since any official report was thought more of abroad, and might have had the effect of hampering manufacturers of engines to a considerable extent in their foreign orders; but he hoped that with the accompanying replies of the Surveyor not much injury would be done by the recommendation in the report. It was however advisable that engineers should give the results of their experience on the subject, and by a clear statement of facts aid in establishing correct views upon this important question.

The Chairman enquired whether Mr. Marten used both hot and cold blast at his works, and whether he considered that with the same materials the hot-blast iron was as good as cold-blast.

Mr. Marten replied that he made only hot-blast iron at his works, and considered that within a small percentage it was as good as cold-blast when made from the same materials and in properly adapted furnaces, that is larger and with wider throats; while the use of hot blast was attended with several advantages: with the same material much less fuel was required per ton of iron produced when hot blast was employed, and much more iron per week from the same furnace could be obtained; a more uniform quality of iron was produced, and they could generally calculate on greater regularity in the working

of the furnaces with hot blast, the cold-blast furnaces being more liable to be affected by fluctuations in the state of the atmosphere.

Mr. Neilson remarked that in reducing iron from the ores in which it was found, the first point to be noticed was that a high temperature was required to effect the reduction: formerly with the cold blast the heat was only just raised to about the melting point of the ore, and accordingly the point of fusion was so near the limit of temperature that could be obtained in the furnace that the heat was constantly liable to drop below that point; and whenever the heat was lowered even slightly, a scow would come on, as it was termed; the furnace began to work badly and black slag was immediately produced, containing an excess of iron running away to waste. But a great difference was made by the introduction of the hot blast, the temperature of the furnace being altogether raised considerably, so that a good margin was left for fluctuations in the temperature without affecting the quality of the iron made. Moreover with the cold blast the point at which fusion of the ore took place in the furnace was at least 2 feet height above the level of the tuyeres, the coldness of the blast on entering the furnace preventing the fusion from taking place at a lower level, so that the melted iron was obliged to trickle down 2 feet through a sort of refinery, thereby becoming partly decarbonized and injured in quality. But with the hot blast the temperature necessary for fusion was attained within 6 inches height above the tuyeres, and the melted iron dropped down immediately into the hearth, where it was protected from the blast by the scoria floating on its surface. A striking instance of the change produced by the adoption of hot blast he remembered at the Muirkirk Iron Works, where the furnace was previously making good iron with cold blast: but on applying the hot blast at a temperature of about 400° or 500° with the same burden on the furnace, the first cast gave iron so rich with carbon that it was quite useless from its weakness; the pig broke with its own weight, and the iron was soft almost like plumbago, so that it could be cut with a knife. This was speedily remedied by taking off some of the burden of the furnace, and using more ironstone, less limestone, and less fuel, so that the iron was less highly carbonized, to compensate for its being less decarbonized in passing the tuyeres: the furnace

was then in a few days restored to the right working, and yielded iron equal to No. 1 cold-blast.

In comparing hot and cold-blast pigs an important point to be noted was that a relatively higher number had to be taken in hot-blast iron to correspond with the same quality in cold-blast; and the want of observing this essential distinction formed a great impediment against the use of hot-blast iron at first, as it was sold by the cold-blast numbers; and the mistake was set right only after a lengthened experience of the qualities of hot and cold-blast pigs. Thus No. 1 hot-blast was weak compared with No. 1 cold-blast; and a finer fracture than No. 1 was required to give the same strength as No. 1 cold-blast, No. 2 hot-blast corresponding with No. 1 cold-blast.

The use of hot blast afforded the means of extracting iron from almost any substance containing it, but the strength of the iron thus obtained depended of course upon the materials it was made from; if these were of inferior quality the iron could not be expected to stand a severe test. The relative quality of hot and cold-blast iron was fairly determined only when both were made from the same materials; and his own opinion was decidedly that if the same materials were employed and the proper numbers taken for denoting the quality, the hot-blast iron was fully as strong as the cold-blast. The experiments made by Mr. Hodgkinson and Mr. Fairbairn in 1837 for the British Association proved conclusively that hot-blast iron was as strong as cold-blast, when made from the same materials; and therefore it was very desirable that the erroneous views entertained respecting the two descriptions of iron should be taken up and set right.

Mr. C. Markham believed a general conviction prevailed that cold-blast iron was superior to hot-blast: he was aware that the experiments made some years ago by Mr. Stephenson previous to the construction of the High Level Bridge at Newcastle, which were probably the most comprehensive and accurate experiments that had been made, showed that hot-blast iron had nearly the same strength as cold-blast; and those experiments confirmed previous and subsequent ones. All the experiments that he was acquainted with had been made with bars subjected to a gradually increased weight: but he believed that cold-blast iron was much stronger than hot-blast in

resisting fracture by impact, and it was desirable that experiments should be also made with bars tested in that manner. Cold-blast iron both in pigs and bars had always obtained the best prices; and it was the general belief that the best iron made in this country was from cold blast. In Derbyshire hot-blast iron was made almost exclusively: but recently Mr. William Fowler of Sheep Bridge Iron Works near Chesterfield had commenced working one of his furnaces with cold blast; he had seen some of this iron at Messrs. Taylor's works at Leeds, which was broken with great difficulty and was much superior in quality to any iron he had previously seen in Derbyshire; the wheel tyres that were made from a mixture of this iron appeared to be of excellent quality.

The Chairman thought the general impression that cold-blast iron was stronger than hot-blast was entirely owing to the inferior materials sometimes used in making hot-blast iron; but the comparison should be made only between pigs smelted from the same materials. His own experiments showed that hot and cold-blast iron were of about equal strength when made from the same materials.

Mr. R. Brown remembered casting some girders for Mr. Jesse Hartley for the Liverpool Docks, in which a greater strength than usual was required, and was obtained by mixing various hot-blast irons from Scotland, using generally No. 3 hot-blast with a little of No. 2; which gave a better test bar than he could get with cold-blast iron. He also obtained excellent tests from a mixture of North Wales hot-blast irons of the same numbers. The test bar was 1 inch square and 54 inches length between the supports; and the breaking weights were from 600 to 700 lbs., the average deflection being 1½ inch.

Mr. E. Jones had also cast a number of girders some years ago for Mr. Hartley, for warehouse floors at the Liverpool Docks, the testing of which was unusually severe, each girder having a test bar cast upon it, which was broken off at the warehouse and tested; the bar was 2 inches deep by 1 inch wide with 36 inches bearing, and had to carry 30 cwts. in the centre. The iron that he found best was a mixture of 3-5ths hot-blast Scotch, 1-5th hot-blast hematite, and 1-5th good cast scrap; this produced a very strong casting, and the only one capable of standing the required test.

The Chairman asked whether Mr. Neilson had seen the new oval hot-blast oven that had been described in the paper, and what was his opinion of the plan.

Mr. Neilson said he had seen the improved oval oven with core at the Parkfield Iron Works, and was much pleased with the construction; he could fully believe the statement given of its greater durability, from the length of time it had continued in regular work without any defect of the joints or pipes occurring; he was satisfied it was the best hot-blast oven he was acquainted with. The use of the firebrick core was an important advantage, rendering the oven less liable to irregularity of temperature, and causing greater uniformity in the quality of the iron produced; for a variation of only a small amount in the heat of the oven affected the make of iron, and might be occasioned in the ordinary ovens by carelessness of the fireman; but the variation could not take place to such an extent with the firebrick core, which acted as a magazine of heat, containing a heating power that was not easily reduced. Other ovens might no doubt be made a little cheaper in construction; but the additional cost of the oven would be well returned by its superior durability and economy of working.

Mr. H. Smith enquired what loss of pressure was found to be occasioned in the blast by its passage through the oven.

Mr. Marten replied that the loss was very small, amounting to only about $\frac{1}{4}$ lb. per square inch from the engine to the tuyeres; if the pressure of blast at the engine were $3\frac{1}{2}$ lbs. per square inch, it was found to be very nearly $3\frac{1}{4}$ lbs. at the plug hole next the tuyeres when carefully measured by a blast indicator. With the oval ovens he had found a great saving in the quantity of blast required to be supplied from the engine; the number of strokes was reduced as much as one fifth, saving one fifth of the whole blast, equivalent to blowing five furnaces with the same engine power as four. The supply of blast required for four furnaces was reduced from 18,000 or 20,000 cub. ft. per min. to 14,000 or 15,000 cub. ft. per min., entirely in consequence of the reduction of leakage in the oven.

Mr. H. Smith said the loss of pressure stated was much smaller than in the ordinary ovens, in which he had frequently found a loss of $\frac{3}{4}$ lb. per square inch and upwards, when the pressure at the engine was about 4 lbs.

Mr. Marten said that no leakage could be detected with the oval ovens, and the loss of pressure was solely that due to the friction of the pipes; but he had experienced a great loss of pressure amounting to fully $\frac{3}{4}$ lb. with the ordinary ovens, before adopting the improved oval ovens, which must have arisen from the great leakage unavoidable in the ordinary ovens in consequence of the constant straining of the socket joints of the arch pipes caused by expansion.

The Chairman moved a vote of thanks, which was passed, to Mr. Marten for the valuable information he had furnished in his paper; and also to Mr. Neilson for the very interesting account he had given of the history of the hot blast and his long experience in connexion with the subject.

The following Paper was then read:—

ON THE APPLICATION OF THE DECIMAL SYSTEM OF MEASUREMENT TO MECHANICAL ENGINEERING WORK, &c.

BY MR. JOHN FERNIE, OF DERBY.

The subject of a Decimal system of Measurement has been for some time under the consideration of the Institution, having been brought before the annual meeting at Glasgow in 1856 and at Manchester in 1857 by communications from the last President, Mr. Whitworth, in which the desirability of a uniform decimal system of measurement in place of the present method of irregular and complicated fractional divisions was pointed out, and its important advantages shown in simplicity of notation and convenience for general use, and accuracy in consequence of the removal of the source of error caused by mixed fractions. For the case of mechanical engineering work—the branch of the subject now more particularly under consideration—as well as for metal manufacturing purposes generally, a definite plan of taking the inch as the standard, divided into 1000 parts, was proposed by Mr. Whitworth; which was approved by the meeting as the most eligible plan for carrying the system into practice, and the Council of the Institution were requested to act as a committee for getting the plan developed into working shape, and taking steps to facilitate its being brought into practical use. As a step towards this object, the decimal system of measurement is being carried out in the Proceedings of the Institution; and the writer has now been requested, as one of the Council, to bring the subject forward before the members at the present meeting, for a further discussion and consideration of the details connected with the introduction of the system into use in the workshop. Having been occupied some time in practically carrying out the decimal system of measurement, and having had the opportunity of commencing its application in the locomotive shops of the Midland

Railway at Derby, the writer has become strongly impressed both with the practical value and importance of the system for universal shop use, and with the complete practicability of its adoption with much less real difficulty than may appear at first probable, and without involving any objectionable changes. He has also found a very general agreement, as far as he has had opportunity of collecting opinions on the subject, in the desirability of adopting a decimal system of subdivision in place of the present irregular fractional method; the difference of opinion being only as to the best mode of carrying out the system, and the best unit to be adopted.

The establishment of a *decimal system of subdivision* is certainly the main point of importance, and the question of the special standard to be taken as the *unit of measure* is of comparatively secondary importance: the first point to be aimed at being to avoid adding the difficulty of any new standard, which would totally change the present measure; but to select one single standard and work entirely by decimal subdivisions; selecting as the standard the measure most eligible for the purpose, as having already the greatest universality of use combined with greatest convenience for decimal subdivision, and consequently involving the least amount of change in introducing the new system: providing that this measure is not unsuitable from other sufficient causes. Mr. Whitworth's proposal of the *Inch* as this standard appears to the writer to have such a preponderance of reasons in its favour, as to be the only one suitable for practically carrying out the system at the present time; and in reference to this part of the subject, it is important to keep in view that the object to be aimed at is the arrangement of a plan suited for introducing the decimal system of measurement at once into our shops for regular universal use, and not involving any change so great as to amount in effect to a further indefinite postponement of the subject and to risk the loss of the object altogether. The surest mode of bringing about the change in this country, and apparently the only one likely to be available, is for the plan proposed to have such advantages as to overweigh the attendant difficulties, and make it the interest of the parties who will have to use the new measure to adopt it themselves and exert their influence to extend its use.

An important example bearing on this consideration is afforded by the recent successful attempt made to establish a standard universal measure of 100 lbs., named a cental, for grain and other articles of commerce, for which a large variety of different measures, forming irregular fractional divisions of one another, have been hitherto used in different parts of this country; this change has been brought about by the parties using the measures having agreed to it as advantageous to themselves in convenience, simplicity, and accuracy.

As regards the French Metre system, which has also been proposed for the present purpose, and offers the two great advantages of being already a complete decimal system ready matured, and one in extensive use on the continent: however desirable it would undoubtedly be to have one universal language of measure over the world if practicable, there is this apparently fatal objection, that the complete change involved in substituting an entirely new standard of measure in this country, and the consequent entire change in the present practical data, rules of calculation, and habits of mechanical thought, would be an adjournment of the whole question for the suitable education of at least another generation, even if it be practicable at all to effect such a change in this country. It has also to be borne in mind what a large portion of the civilised world already uses the English inch with the English language, in America, Australia, &c. Also this consideration does not appear to be affected by any strong advantage in the Metre as a unit for the purpose, or any practical disadvantage in the Inch; for although the latter is undoubtedly a small dimension, it is already the standard in regular use for a great portion of mechanical engineering work, inches alone being habitually used in preference to feet and inches for many purposes, as for cylinder diameters and sectional areas &c., as well as in calculations of steam pressure, strength of sections, &c. Even in the case of the larger dimensions, as in bridge girders &c., it may be noticed that no more figures are required in most cases to give the dimensions in inches than in feet and inches; and indeed up to 80 feet, one figure less is required with inches for some of the dimensions: thus 959 ins. with three figures equals 79 ft. 11 ins. with

four figures. In the case of metres, the smallest dimension of line measure, namely the millimetre or thousandth part of a metre, which has to be in constant use, requires three places of decimals, ·001 metre; but the corresponding smallest dimension of line measure in inches takes only two places of decimals, ·01 inch: an advantage of importance both for figuring working drawings and for reading by the workman. Also the millimetre being ·04 inch or 1-25th inch nearly is not quite fine enough for the purpose, being 1-3rd larger than 1-32nd inch or ·03 inch nearly which is frequently used in practice, and consequently requiring half millimetres or tenths of millimetres to be used occasionally.

The accompanying diagram Fig. 7, Plate 26, shows to the natural size the two decimal scales of the inch and the metre as above referred to: one tenth of a metre is shown divided into thousandths of a metre or millimetres; and the inch scale is divided into tenths and half tenths, each of the subdivisions being ·05 inch (5-100ths of an inch), and the first tenth is divided into hundredths.

Then as regards the means of verifying the standard, the metre appears at first to have a superiority in being a more definite dimension, being originally fixed as the 1-10,000,000th part of a quadrant of the earth's circumference from the equator to the pole, a distance measuring altogether about 6000 miles; whilst the inch is derived from the length of a pendulum beating seconds in a vacuum at the level of the sea in the latitude of London, the length of which is not an exact number of inches, but 39·14 inches, or more accurately 39·13929 inches, say 39 inches and 139290 millionth parts. This superiority in the metre is however rather nominal than real, for the process of verifying the measure of the standard is one of approximation which can be carried only to within a certain number of places of decimals in either case; and in addition it appears from subsequent more accurate measurement that the standard metre really differs by the correction of a small decimal from the exact 1-10,000,000th of the quadrant, owing to a slight inaccuracy in the original measurement. It may be remarked as a rather singular circumstance that the present parliamentary standard of English measure, the yard, is fixed at 36 inches, of which the second's pendulum is 39·13929 inches; so that in effect the inch is the present legal standard.

The general result arrived at is then that the *Inch* is the most suitable as the unit of measure for mechanical engineering work, including a wide range of manufacturing work generally: and in order to enable a definite step to be effected it appears strongly advisable to make a start on that basis as sufficiently complete for the purpose; without encumbering the question with considerations as to probable further steps in the direction of decimal multiples of the inch for higher measures, (such as a 10 inch foot, or a 100 inch measure, which is near the dimension of the present 10 foot rod folding in two lengths, ordinarily used in builder's measurement,) as this would be premature in the present instance, and lead only to further postponement of the whole question, from the further practical difficulties to be encountered.

An important step has already been effected in the course of establishing the system, by the Decimal Wire-gauge which Mr. Whitworth has completely carried out; by means of which the smaller sizes of work can be accurately reproduced at any time, in consequence of the Nos. of the decimal wire-gauge being definite dimensions, forming one single series, as convenient for use as the old complicated system, and avoiding the confusion of several distinct Nos. being used to represent the same size, and the uncertainty as to the exact value of each size in cases of reproducing work or of difference between gauges. No alteration is made in the sizes ordinarily used, their names only being changed to one uniform series representing the exact value of each in thousandths of an inch. As an example the following five gauges in ordinary use all represent the same size:—

No. 20 Ordinary or Birmingham Wire-gauge.
No. 62 Lancashire Wire-gauge.
No. 13 Metal or Plate-gauge.
No. 18 Music Wire-gauge.
No. 3 Needle Wire-gauge.

and there is substituted in place of all these different Nos.

No. 36 Decimal Wire-gauge,

the dimension being 36-1000ths of an inch.

This is an important point accomplished, and has now been completely carried out by Mr. Whitworth, who has been also extending

the set of standard plugs and gauges made by means of his extremely accurate measuring machine ; and has now got a complete series from 1-1000th inch up to 6 inches, rising by successive steps of 1-1000th inch at first, with increasing intervals as the sizes increase, so as to include every size required in work, of any of which exact duplicates are readily supplied ; so that, for all work of contact measurement or measurement by touch, there is now the means of obtaining a standard measure to the highest degree of accuracy appreciable.

Since a complete set of these gauges would be out of the reach of shops generally, and only a few leading standard sizes in most general use can be kept, there becomes requisite, as the next step in carrying the decimal system into use in the workshop, a means of enabling the workman to measure the intermediate sizes with corresponding accuracy, that is with a degree of accuracy corresponding to the accuracy with which he is able to execute the work. Now with the present improved style of tools and work, the difference of 1-1000th of an inch is distinctly felt and appreciated by a good workman in regular mechanical work, such as the clearance in steel pins working in steel eyes, fitting wheels on axles, boring gun-barrels, &c. ; and in wire-drawing there are six sizes made smaller than ·004 inch or the old No. 36 Birmingham wire-gauge, which must therefore differ by less than 1-1000th of an inch from one another. It follows then that means of contact measurement or gauging is required for each 1-1000th of an inch up to the largest size employed,. in order to carry out the system completely. The first step for accomplishing this is to obtain some mechanical arrangement for accurately multiplying or magnifying the dimension, so as to get the 1-1000th of an inch represented by a space plainly visible and readily counted, say 100 times magnified making it thus 1-10th of an inch.

Several ingenious plans have been devised for this purpose, on different principles for obtaining the required multiplication : the simplest form by a sliding wedge, in which the longitudinal motion is equal to the transverse motion magnified in the proportion of the length to the height of the wedge ; as in the accompanying model shown at a former meeting by Mr. Ramsbottom, in which a longitudinal motion of 10 inches gives a transverse motion of 1 inch, or

1-1000th of an inch is represented by 1-100th of an inch, being magnified 10 times.

The spiral measuring instrument shown, made by Mr. James Cocker of Liverpool, is an ingenious example of the same principle, in which the wedge is bent round into a circle forming a spiral of about 10 inches length of circumference; and one revolution of the steel spiral, or a longitudinal motion of 10 inches, gives a transverse motion of ¼ inch or the pitch of the spiral, thus multiplying the motion 40 times, and magnifying each 1-1000th of an inch into ·04 or 4-100ths of an inch or a little less than half 1-10th of an inch. The successive ¼ inches are obtained by drawing back the abutment or back centre successively by a ratchet of exactly ¼ inch pitch, thus giving the means of measuring up to 2 inches. This instrument has been in regular use for some months in the locomotive workshops at Derby.

From his experience of the working of this instrument, the writer has been led to desire an instrument capable of taking in larger dimensions, and more permanently correct by avoiding any source of error arising from wear in the working parts. The principle of Mr. Whitworth's measuring machine appears to him after trying several plans to be the best suited for this purpose; and the machine now exhibited is made on that principle. It consists of a very strong cast iron bed, with a V groove planed out along the top surface; at each end wrought iron straps are attached. At one end a bar of steel 1 inch square is grasped by one of the straps, so that measuring may be performed, but if any undue pressure were put on it would be moved back without straining the machine. At the other end of the bed another square steel bar is made to slide steadily through the strap; the outer end of this bar has a screw of 10 threads to the inch chased on it, and a double nut and hand wheel 10 inches diameter works it out and in, having rather more than 1 inch longitudinal movement; the wheel is 2 inches wide on the edge, and a spiral line is drawn upon its circumference, upon which the divisions are afterwards marked. Short bars of steel 1 inch square, but reduced at the ends to ¼ inch diameter, bearing in the groove of the bed the same as the pieces already described, are used to fill up the machine.

The first thing now required is to get a standard inch, and having put it in the groove of the machine the gravity piece is placed up to it, and the rest of the machine then filled up with pieces of steel, or the back centre brought up; the screw is then advanced until the gravity piece will only just fall, and this point is marked by the index on the first spiral of the dividing wheel; and then removing the inch standard the wheel is turned until the gravity piece is brought forward through the space left, being an exact inch, and will again only just fall, and this place is marked by the index on the last spiral of the dividing wheel. The whole distance between the first and last marks upon the spiral line has then to be divided into 100 equal parts and each of these divisions again into 10; and a machine is then obtained which will measure correctly ·001 inch. As each ·001 or 1-1000th of an inch measured is equal to ·3 or 3-10ths of an inch on the wheel, this might be again subdivided to work to ·0002 or 1-5000th of an inch. This machine is made for working to all the ordinary sizes used in a locomotive shop, and will take in from 13 inches downwards; and all dimensions for the different parts of the engines are being made from it with the inch standard now shown, the other bars being made from the inch standard: first another inch piece is made, then a two inch piece, and so on till the required number of pieces are made.

In order to make the system still more complete for railway work, a machine to measure up to 100 inches would be of great use; not so much delicacy of workmanship would be required, and 1-100th of an inch would be almost fine enough for this machine; the screw might be made with 5 threads to the inch and traverse 5 or 10 inches: there would then be a perfect gauge for keeping to one correct size almost every piece of work in a locomotive engine. Gauges could be made for the exact length of the axles, the distance over and between the journals; so that all might be made with great exactness and tested at any time as to accuracy. But the importance of such a gauge would be most felt in the wheel department; with such a machine every wheel might be turned to exactly the same diameter, and instead of the present plan of allowing a full 1-8th or bare 3-16ths for shrinkage, a certain amount in proportion to the circumference of the tyre and within 1-100th of an inch of what is really required might be given

with a degree of certainty which could not be attained by any other method.

As a first start then the writer considers it indispensable that a measuring machine should be made, from which dimensions can be taken at any time and at any time these dimensions verified; taking the inch as a standard all the other parts must be multiples or decimal divisions of it. The screw for the finer divisions should be as fine as possible, consistent with standing ordinary work; and the nut should be in two pieces so as to be let together at any time to compensate for wear: the machine should take in at least 10 inches. It should be under the charge of one man, who would give all dimensions and see that it was carefully used and locked up when out of use; and as a first step all workmen's rules should be tested by it, after which dimensions for different parts of the engines might be given. As an instance, the pins and links for the valve motions of locomotive engines after being turned and bored are casehardened, after which they are ground into their places: in casehardening there is usually an expansion of the pin and a contraction of the hole in the link end; by the use of the measuring machine this can be carefully measured, and on a 1½ inch pin it amounts to ·002 inch expansion, and in the hole the contraction amounts to nearly the same; so that now the workman when he wishes to make a pin 1½ inch diameter turns it ·002 inch less and bores the hole ·002 inch larger, and the grinding in is consequently brought to a minimum: the quantity of clearance required being also ·002 inch, the pin requires only ·001 or 1-1000th inch ground off it, and the hole is lapped out to the same extent to give the proper amount of play. Also with the bosses where levers are keyed on, and especially the axles and centres of railway wheels: these are at present carefully turned to templates allowing a certain amount of excess in the axle so that the wheel may press tightly on it; but in addition to this quantity being it may be said empirical, there is no way of correcting the wear and tear on these templates; and since the wear is considerable, a variation in dimensions arises which is far from desirable in a large rolling stock. The advantage of working to such an amount of accuracy would soon be felt in the

workshop: everything would go into its place with the exact amount of clearance or the exact degree of tightness required; there would then be no need of the file to ease a boss that was too tight, or of tin liners or centre punch marks for a wheel that was too loose.

As regards the coarser measurements in the workshop the only change involved will be supplying new rules for the men in place of those now in use; these rules should be 20 or 30 inches in length and jointed for convenience at every 10 inches, each inch being divided into 10 parts, having between each of these divisions a small point or short mark representing half 1-10th inch, as shown in Fig. 7, Plate 26; the workman is then soon able with a little practice to subdivide this again by eye so as to measure to 2-100ths or even 1-100th of an inch: one tenth of an inch upon the brass part of the rule is divided into hundredths of an inch for the purpose of reference at any time. The exchange of rules in this manner is not a new practice: the late firm of Bodmer of Manchester the writer believes used always to supply rules to all new workmen taken into their employ; and Mr. Whitworth has taken the initiative in this matter by supplying all his men with new rules 20 inches long, having each inch divided into tenths; one of these rules is laid before the meeting, and their cost in quantities is 1*s*. each. The writer apprehends no difficulty in the men learning the new system of measurement; for it is from a complex to a comparatively simple system that the change is to be made, the advantages of which must soon be apparent to every workman; and this conclusion is borne out by the experience of several gentlemen who have had occasion to manufacture stock for foreign railways, for which the dimensions were in metres and millimetres, who found no difficulty consequent on the introduction of the French metre into the workshop, but on the contrary found that the men got to like the decimal divisions better than the common divisions into eighths, sixteenths, &c.

The change involved in drawings is but a small affair. Instead of figuring the dimensions as at present in feet and inches and fractions of an inch, inches and decimals only have to be put down; and this for ordinary engine drawings will be a great improvement on the present plan, as well as a gain in consequence of fewer figures being required up to a certain dimension, as has already been shown. It will also

prevent mistakes which the writer has met with in reading off dimensions, from workmen mistaking such numbers as 2 ft. 1½ in. for 21½ ins., whereas it would be impossible to misunderstand 25·5 ins. When the size of the paper will admit, drawings made on a scale of 1-10th or 1-5th of the full dimensions would be more convenient than those at present made to a scale of 1 inch or 1½ inch to the foot or indeed any odd scale; but the present use of drawings figured in feet and inches would be no barrier to the introduction of the decimal plan; or even if the scale of 1½ inch to the foot or 1-8th full size were preferred for convenience of size, all that would be required would be to figure all dimensions on new drawings in inches and decimals.

The writer has now touched upon all the various details in the application of decimal measurement, as they have been brought under his notice in practically introducing the system. A great deal has been already done by Mr. Whitworth; but the practical adoption of the system throughout the workshops of Great Britain, and it may be added of America, rests with such men as the mechanical engineers, whose decision will be far more useful than an act of parliament. The advantages of other applications of the decimal system, whether in monetary matters or in weights and measures, have long had the approval of the intelligent classes of the community; and it only requires the active co-operation of the members of this Institution and their friends to accomplish for the mechanical engineers and manufacturers of Great Britain what has been so successfully done by the commercial men of Liverpool and Hull in their adoption of the cental of 100 lbs. instead of the clumsy bushel of different weights in different localities. It will be observed that throughout this paper the writer has kept entirely clear of a question which may be introduced into the discussion, but which does not strictly belong to mechanical engineers: namely how to proceed with the measurement of land &c., with the present chains and links, square feet, square yards, poles, roods, and acres. The writer is not prepared to enter upon this question at present; but he thinks there will scarcely be any who do not condemn the present system of land measurement as inconvenient and cumbersome. But

however desirable it would be to have a system of measurement capable of taking in all measures required, this could be accomplished only by an act of parliament; and a glance at the manner in which parliament has dealt with the pound and mil scheme, the most feasible plan for introducing the decimal system into the currency, is enough to show that the question would then be postponed for a lifetime at least. Feeling satisfied that the inch is best suited for the decimal system of measure, that its decimal subdivision tends to simplify rather than complicate the present method, and that the introduction of this decimal system of measure will be productive of important advantages while involving no objectionable changes, the writer confidently trusts that its general adoption in the drawing office and the workshop will soon be carried out.

The CHAIRMAN exhibited his measuring machine for measuring lengths or thicknesses to the millionth of an inch, and showed its action. The principle of the machine is simply to compare the end measure of a bar or other piece with a corresponding standard bar of known length, and to ascertain their exact difference of length; the new piece is first made slightly too long, and then gradually brought to the exact length of the standard by successive processes of shortening and remeasurement. The principle is the same as that of measuring by ordinary callipers for end or outside measurement, only that in the latter process the accuracy of measurement is limited by the uncertainty and irregularity in the tightness of fit of the callipers upon each of the two pieces successively gauged by them, causing a variation in the measure obtained on account of the elasticity of the instrument allowing it to yield to a variable extent with the variable pressure of contact. In Mr. Whitworth's machine this pressure of contact between the measuring callipers and the ends of the piece to be gauged is exactly regulated to the same amount in every case, by causing a small parallel steel plate, called the *gravity piece*, to be held suspended between the two surfaces by this pressure of contact; the surfaces being in each case

gradually brought together by a fine micrometer screw, until the fact of the gravity piece becoming suspended between them instead of falling freely marks that the exact limit has been obtained.

The machine is shown in Figs. 1 to 4, Plate 24, one third full size: it consists of a rigid cast iron bed A, having two heads like lathe heads, fitted with sliding square bars B and C, each advanced by a screw of 20 threads per inch; the bed has a right-angled V groove between the heads, corresponding exactly with the square sliding bars; all the surfaces are made true planes and accurately at right angles. The standard bar for measurement D is also square, as shown full size in Fig. 10, Plate 26, fitting exactly in the V groove of the bed; and the ends of all the bars are reduced to a circular plane truly at right angles to their axis. In adjusting the machine the bar B, shown uncovered in the plan, Fig. 3, is first advanced by means of the divided wheel F fixed upon its screw and having 250 divisions on its circumference, each division giving a motion of 1-5000th of an inch; and the final fine-adjustment is then given by moving the bar C by means of the second-motion wheel G, which has also 250 divisions on its circumference, but carries a tangent-screw H driving a wheel of 200 teeth fixed upon the screw of the bar C, each division of the wheel G consequently giving a traverse of 1-1,000,000th of an inch to the sliding bar C. The gravity piece E rests at each end upon the projecting edges of the bed, and is moved vertically by the finger between the end of the standard bar D and of the sliding bar C: it is lifted at one end into the position shown by the dotted lines in Fig. 4, and at first falls freely when released; the sliding bar C is then gradually advanced by means of its screw until the pressure of contact is sufficient to support the weight of the gravity piece, which then remains suspended between the ends of the bars when lifted, still moving freely when touched but not being able to fall by its own weight. The exact position of the wheel G is then noted, by observing the reading of the divisions on its circumference: the standard bar D is then removed, the bar C being drawn back by the wheel G. If it be required to produce a duplicate of the standard bar D, the proposed duplicate is put into the machine, its ends being made true planes at right angles

to its axis; one end of the duplicate is placed in contact with the end of the bar B, which has remained unmoved since the last measurement; the gravity piece E is lifted by the finger and allowed to fall between the other end of the duplicate and the end of the bar C. The bar C is gradually advanced by means of the wheel G, until the fall of the gravity piece is just arrested; the reading of the wheel then indicates whether the proposed duplicate is of exactly the same length as the standard, and shows the difference to the millionth of an inch.

The machine was exhibited in action by the Chairman at the close of the meeting, showing that an advance of ·000001 inch (1-1,000,000th of an inch) was distinctly indicated by the gravity piece becoming suspended instead of falling; and the turning back of the divided wheel through two divisions, representing ·000002 inch, was then sufficient to cause the gravity piece to drop, and included consequently all the play in the four bearings of the two screws and two collars. The Chairman showed also that the fineness of measurement obtained by the machine was sufficient to detect the expansion in length of an inch bar caused by a momentary touch of the finger, the bar then measuring ·000001 inch longer than previously; (the expansion of iron being about 1-150,000th of its length for each degree Fahr., a rise of temperature of 1-7th of a degree expands an inch bar 1-1,000,000th of an inch). He stated that in his larger machine for measuring the standard yard, with a bar 36 inches long the same amount of expansion was shown by the momentary contact of the finger nail. The finest measurement required the precautions of freedom from dust and moisture in the atmosphere, and from any current of air interfering with uniformity of temperature; and the machine was therefore kept in its glass case during the time of use, with an opening only sufficient for moving the micrometer wheel and lifting the gravity piece; by sufficient care in these respects the measure of a space corresponding to half a division on the wheel or 1-2,000,000th of an inch had been rendered distinctly perceptible.

Specimens were exhibited of the Decimal Wire-gauges made by Mr. Peter Stubs of Warrington from Mr. Whitworth's standard gauges, having the new decimal Nos. on one side from No. 18 to 300, measuring ·018 to ·300 inch, and the corresponding old wire-gauge

Nos. 26 to 1 on the other side. Also specimens of the Decimal Rules made by Mr. Sampson Aston of Birmingham from Mr. Whitworth's standard 30 inch steel bar; 20 inch flat jointed rules corresponding to the ordinary 2 feet workmen's rules, and 30 inch folding rules (2½ feet) divided on the four sides. It was stated that the decimal wire-gauges were now regularly supplied by the maker at 7*s.* 6*d.* each; and the decimal rules at 1*s.* to 3*s.* each, several hundreds of the 20 inch rules being already in use.

A small measuring instrument of foreign invention was shown, made by Mr. Alfred Knight of Birmingham, in which small dimensions are indicated to one thousandth of an inch by an index upon a graduated arc, the indication being magnified by means of a rack and pinion, with a spiral spring upon the axis of the index to keep the teeth of the rack and pinion in uniform contact in the same direction, preventing any error from play.

Mr. J. Cocker showed his decimal measuring instrument, for measuring small sizes to one thousandth of an inch, consisting of a flat graduated disc, about 3½ inches diameter, the edge of which is formed in a spiral shape with exactly ·250 inch pitch of the spiral, having a sliding bar as an abutment placed in the plane of the disc and just touching it at the greatest projection of the spiral. The circumference of the disc is divided into 250 parts, each representing ·001 inch; to obtain any dimension the disc is turned round into the proper position, and the space between the spiral and the abutment gives the dimension required. He showed also a smaller measuring instrument on the same principle, intended as a wire gauge, in which a stud is fixed upon a radial arm turning on a pin in the centre of the disc, and the required dimension is the space between the stud and the spiral edge of the disc at any point.

He stated that his object in the smaller gauge had been to carry out the idea of decimal measure by means of a gauge suited for measuring small dimensions with accuracy, and particularly for measuring wire; he had been led to it by experiencing so much difficulty in obtaining the exact sizes of wire required, from the want of a correct and reliable wire-gauge. He had had the idea of the small gauge now shown for many years, and considered it had an advantage

in giving all the intermediate dimensions for every thousandth of an inch; it was also light and compact and could be easily carried in the pocket. In the larger measuring instrument his object was to meet the requirements of mechanical engineering work generally, and for this purpose the size of the spiral disc was increased, to give larger graduations for each thousandth of an inch; by turning the disc round any dimension was obtained up to ·250 inch, and larger sizes were measured by means of the moveable bar forming the abutment, which was made with notches at intervals of ·250 inch, having a pall to hold it at any required notch: by this means any dimension up to 2 inches could be taken correctly to one thousandth of an inch. The spiral disc was turned back to the zero position by means of a weight, which gave a uniform pressure upon any article inserted in the gauge for measurement, and prevented risk of the instrument being strained by hand in taking a dimension. This measuring instrument had now been in use nearly twelve months in some railway shops; the object was to get a simple instrument for accurate measurement at such moderate cost as to allow of its introduction into shops as a calliper gauge.

The Chairman asked what was the cost of the instrument, and whether one thousandth of an inch was the limit of accuracy to which it could be used.

Mr. J. Cocker replied that the cost of the measuring instrument for dimensions up to 2 inches was £5, and that of the small pocket wire-gauge £1 1*s*. The instruments at present made measured only to 1-1000th of an inch, but the size of the measuring disc could be increased so as to measure to 1-10,000th of an inch or even finer if required: he contemplated making an instrument with 1 inch pitch of the spiral, to be used for the coarser measurements of the workshop.

The Chairman observed that in the decimal wire-gauge that he had recommended he had simply taken the sizes of the old iron wire-gauge, using all those that were accurately represented by thousandths of an inch, and avoiding a change of the sizes now in regular use. All the change he proposed was to call these sizes by a fresh number indicating their exact value in thousandths of an inch. In order to obtain great exactness the decimal wire-gauges were made from standard flat gauges, as shown full size in Fig. 8, Plate 26;

the two faces of the gauges were true parallel planes, and he found there was no difficulty in making these standards correct to 1-40,000th of an inch by means of the measuring machine, from the great accuracy of the sense of touch: a separate gauge was made for each notch in the wire-gauge, and a set of these originals he had supplied to Mr. Stubs from which the decimal wire-gauges now shown were made. The standard gauges for larger dimensions were made in a cylindrical form, from ·10 inch up to 6 inches diameter; the smallest size ·10 inch is shown full size in Fig. 9, Plate 26: these were casehardened and got up very true, and lasted a long time as they presented a very large extent of wearing surface. He considered that for the shop the use of standard gauges was better than any measuring machine, on account of the difficulty of using a sufficiently delicate instrument in regular shop work, and the greater liability there would be to alteration in the standards both of diameter and length.

The method of working by end or contact measure was far superior to that of line measure. The latter was the plan previously used, and was adopted for determining the length of the government standard yard measure, which was a gun-metal bar with two transverse lines upon it 36 inches apart: in order to render minute differences of dimension appreciable to the eye a microscope was fixed over each end of the bar, as shown in Figs. 5 and 6, Plate 25, adjusted by a micrometer screw so as to be exactly over the two transverse lines; the two microscopes were fixed in their position by clamping screws, and the bar being replaced by a second one, the transverse lines on the latter could be compared with the original and the difference measured and registered by the micrometer screw. There was however no means of finally correcting the position of the line, but it had to be left when very nearly correct, and the exact amount of error whether in excess or defect then registered by means of the micrometer attached to the microscope. The effect of the microscopes in this case was simply to increase the extent of surface over which the eye traversed in measuring the distance, so as to render minute distances appreciable to the eye; but the extent to which it was found this could be carried by means of microscopes was very limited and uncertain as compared

with the method of end measurement. In the measuring machine a motion of ·000001 inch (1-1,000,000th of an inch) in the screw was represented by nearly ·04 inch upon the circumference of the dividing wheel; so that the machine magnified 40,000 times, and the eye traversed over 40,000 times the space that was being measured.

No practical use could be made of microscopes in the workshop; and workmen could only set callipers to a gauge, and required standards of touch or end measure to work to. With practice the sense of touch was able to detect extremely minute differences of length: by holding a parallel piece, such as one of the wire-gauge standard plugs, between two true-plane surfaces and making them just touch, he could tell though blindfold if one of them were moved 1-50,000th of an inch nearer to the other, by the difference in the feeling of tightness between the surfaces; and with the measuring machine now shown a motion of one millionth of an inch was distinctly perceptible.

Mr. Fernie said they had had Mr. Cocker's measuring instrument at the Midland Railway Works for three or four months, and he had found it so serviceable in the workshop as to lead him to desire a measuring machine giving a greater range of dimensions and more free from sources of error. By that instrument the workmen could calliper easily to 1-1000th of an inch, or less than half the average thickness of a human hair: but a disadvantage in the instrument was that it gave dimensions only up to 2 inches, and required a fresh adjustment of the sliding bar for each ¼ inch; and its accuracy of measurement depended on the pall being fitted exactly home in each notch of the moveable bar; a little dust in the notch or a slight play in the centre pin of the disc would make a perceptible error, the thickness of a hair amounting to more than two divisions on the scale. After considering several plans for the purpose he was satisfied that the only plan suitable for giving the required accuracy was Mr. Whitworth's beautiful arrangement of a micrometer screw and a gravity piece, as seen in Mr. Whitworth's delicate machine now shown; that machine was made with a perfect screw, having exactly 20 threads to the inch, each turn giving an advance of exactly 1-20th of an inch: but there was great difficulty in making a perfect screw, and he found it impracticable with the means at his disposal to get exactly 10 threads per inch; and

to obviate this difficulty he made a screw with as near to 10 threads per inch as his lathe screw would give, and then drew a spiral line on the circumference of the index wheel, the exact length corresponding to a traverse of 1 inch being correctly marked by trial, by the insertion of one of Mr. Whitworth's standard inch gauges in the machine, which might without inconvenience have a little more or a little less than 10 turns length of the spiral.

In the machine he had now constructed on the plan of Mr. Whitworth's his object had not been to measure every pin or other piece of work with the machine, but to make standard gauges for all work where fitting was required, and to have the means of readily verifying these gauges from time to time; the machine would be kept locked up in the charge of one man whose business would be to make the gauges required, and it was large enough to take in any size up to 13 inches.

Mr. R. Brown enquired whether there was any play in the screw, and how it was prevented from interfering with the accuracy of measurement of the machine.

Mr. Fernie replied that the nut after being fitted as truly as possible upon the screw was then cut into two lengths, according to the mode Mr. Whitworth had contrived in his measuring machine and also in the tangent screws of his large tools; and these two portions were let together slightly, shortening the nut upon the screw to that extent and causing it to grip the threads of the screw in both directions: this prevented the slightest play and also allowed the means of tightening it up again at any time to compensate for wear.

Mr. H. Maudslay observed that in those manufactures where many multiples of the same parts were made a system of accurate measurement would certainly be of great service; as in the case of the large gun factory at Enfield, where each portion of the work was made by thousands and with a surprising degree of accuracy. He had recently seen a rifle put together in 2½ minutes, the pieces of which had never been brought together before, but were taken by chance from the lots made of each kind. The absolute gauges of size were essential for such work; but in other cases, as in the regular work of a steam engine factory where few repetitions of the same parts occurred

and they had to change suddenly from perhaps a 500 to a 20 horse power engine, he did not see that the introduction of the system would be of so much advantage. He was quite of opinion however that the plan of decimal measurement should be adopted generally, as a system of greater convenience and accuracy.

The CHAIRMAN remarked that in reference to engines and machinery of different sizes he did not think the advantage of exact measurement was less in practice than in the case of a great repetition of the same articles; for whether an engine were of 500 or 20 horse power an inch and its subdivisions were the same in both, and the same degree of accuracy was required in both, since the best and most satisfactory work was that where the individual parts were accurately made independently by means of gauges, without requiring to be fitted to one another. The best makers of cotton machinery now made the spindles and other working parts by standard gauges alone, and produced the exact fit required in the parts separately, without fitting them to one another before they were finally put together; and the same plan ought he considered to be adopted in all engineering and machine shops, as the most economical as well as most perfect mode of executing the work.

Mr. C. MARKHAM asked the Chairman whether he thought there was any probability of government authorising a standard of end-measure in place of the present unsatisfactory line-measure, which was useless for all mechanical purposes. It was very desirable that a universal standard of measure should be worked to throughout the country: for example, it was important that masons and carpenters should work to the same standard as mechanics in the erection of buildings in which machinery was to be fixed; for if a length of shafting were given in inches and the bricklayers worked in feet there would be a disadvantage. The question of the actual standard he thought was of less importance, provided the same standard was agreed to universally, for the workmen soon became accustomed to a new standard; he had had several years' experience in France in the use of the metre by English workmen, and found that they fell into the use of it in a few weeks, and decidedly preferred the decimal system of subdivision; great trouble and risk of mistakes were caused by the use of 32nds

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and 64ths in adding up a number of dimensions, which were entirely avoided by the decimal system. Mr. Whitworth had certainly rendered great service to the profession by what he had done in promoting the decimal system of measurement, and he hoped he would persevere with it until it became as universally adopted as his system of standard threads for screws had already become.

The CHAIRMAN said that evidence was given by the Astronomer Royal and himself before a select committee of the House of Lords in 1855, with respect to the comparative accuracy of line and end-measure for ensuring a permanent national standard of length. He himself was desirous that the old standard line-measure should be replaced by an end-measure; for in line-measure the limit of accuracy that could be attained by the use of microscopes was practically only 1-10,000th of an inch.

An objection then urged against the plan of end-measure was that its accuracy depended upon the ends of the bar being truly at right angles to its axis, so as to ensure the same measurement at every point of the ends; but this difficulty was completely met by the mode he had adopted for their construction, which was simply an adaptation of the principle of the true-plane that formed the basis of all accuracy in mechanical work. The bar was laid in a grooved bed consisting of two true-planes, as shown in the diagram Figs. 11 and 12, Plate 26, with the ends of the bar and of the bed also true-planes, and approximately at right angles to the longitudinal axis; a trial plane was then applied to their ends as shown by the dotted lines I in Fig. 11, being slightly rubbed to mark the points of contact, and the ends were then reduced to a common true-plane by the ordinary process of scraping. The bar was then turned over, and the same process repeated, taking the correction half off the end of the bar and half off the end of the bed; and by successive repetitions of this process, with the bar resting on each of its four sides alternately, the ends of both the bar and the bed were brought to a true plane at right angles to the axis of the bar, so that the trial plane was in contact over the entire surface of both, in whatever position the bar was placed.

A second objection urged against an end-measure standard was that it was exposed to alteration from the wear of the ends by use:

but the force of this objection disappeared when it was considered that duplicate copies of the original standard could be supplied in any quantity, and the original standard itself would be only rarely used for verifying the copies employed for reference. For the original standard, hard jewelled ends were proposed to be employed.

He further urged upon the committee at the same time to recognise also a standard inch and foot, and to recommend government to have standards of these lengths supplied to the manufacturing towns throughout the country: there was actually no authorised legal standard now used except for drapers' measure. A standard inch and foot of end-measure were finally recommended; but the original standard yard of line-measure was still adhered to, and authorised copies of the end-measure standards had as yet been only partially supplied. Correct standards could be truly obtained only by end-measure; and he had stated that, if government would determine to carry out the system of end-measure, he was ready to make the country a present of his two measuring machines, the inch machine now exhibited and the larger machine which extended to 40 inches in length.

As to the question of government fixing any universal unit of measure by act of parliament, he thought that was not at all likely, and would not be the correct course of proceeding; this should be initiated by those using the measure, and he thought that if mechanical engineers and manufacturers decimalised the inch and worked to it as the unit of measure, adopting this universally for all their dimensions, they could then urge upon government for general use that which their experience had proved to be the best.

Mr. M. Smith thought the decimal wire-gauge introduced by Mr. Whitworth would be of great advantage in the manufacture of wire, as each No. of the gauge denoted the actual dimension in thousandths of an inch, so that there could be no doubt as to the sizes designated by the Nos. At present there was no standard of appeal, and the various wire-gauges differed considerably, both from wear and irregularity in manufacture, so that a sample of the size required had to be sent to ensure obtaining the right size, whenever accuracy was necessary; and he should therefore be very glad to adopt Mr. Whitworth's decimal wire-gauge, in order to have a correct and reliable gauge to

secure accuracy of workmanship. A practical difficulty in drawing wire had to be recognised, arising from the dies wearing so rapidly that the size of the wire varied in drawing a single lot, which made a certain margin of allowance requisite in the size of a quantity of wire; but there would still be the great advantage of having a standard gauge in which each of the sizes was of a definite measure and could be exactly verified at any time.

Mr. I. Smith fully concurred in the great value of Mr. Whitworth's decimal wire-gauge, giving the correct dimensions without chance of error. In the manufacture of split rings great accuracy of size was requisite for the purpose of exactly filling the dies; and he had experienced much trouble from having no means of recording the exact sizes of wire used, except by keeping a sample of each size: he used wire from ·300 inch down to ·004 inch diameter, and had consequently a large collection of samples, some a great many years old, preserved with as much care as possible. He could never find any wire drawer who could draw work to the exact size required without having a sample sent of the size; and this caused great additional trouble and inconvenience. Duplicates of the standard plugs from which the decimal wire-gauge was made would be of great service in the trade, as a means of verifying at any time the gauges in use and detecting any variation produced by wear; many of the gauges now made were not so accurate as was desirable, and the standard plugs would give the means of securing the amount of accuracy required.

The Chairman said he was arranging for the supply shortly of copies of any particular size of standard for the wire-gauge that might be required by manufacturers. He proposed a vote of thanks to Mr. Fernie for his paper, which was passed; and observed that they were much indebted to him for what he had done in bringing the decimal system of measurement into practical application in the workshop; and he was confident that this system of measurement only required to be well discussed and practically tried to lead to its general adoption.

The Meeting then terminated.

PROCEEDINGS.

September 6 and 7, 1859.

The Annual Provincial Meeting of the Members was held in the Civil Court, Town Hall, Leeds, on Tuesday, 6th September, 1859, at half-past ten o'clock; John Penn, Esq., President, in the Chair.

The Minutes of the last General Meeting were read and confirmed.

The following Paper was then read:—

ON FILE-CUTTING MACHINERY.

By Mr. THOMAS GREENWOOD, of Leeds.

It is a remarkable circumstance that whilst almost every manual operation in our various manufactures has been either superseded or very materially assisted by the introduction of machinery, the operation of cutting files is still done by hand, and has hitherto been generally considered to be one not admitting of the application of machinery. Several very ingenious machines for the purpose have already been tried, both in this country and in America, but hitherto without any marked success. Large sums have also been spent by some of the leading makers of Sheffield in attempting to introduce file-cutting machines; but the difficulty of the operation real or imaginary has been one cause of failure, and another cause has been the very determined opposition on the part of the operatives to the introduction of machinery into any part of the various operations of file making: indeed so jealously do the file cutters guard the art and mystery of their craft, that they do not teach their apprentices how to grind their cutting chisel until they have attained the last year of their legal apprenticeship. The manufacture of files has been kept stationary, instead of advancing and improving like other manufactures, from the mistaken belief on the part of the men that by resisting the introduction of machinery they are preserving their employment. As a further illustration of this mistake it may be mentioned that the tariff of prices for forging files now followed is founded upon the supposition that no improvement has been made in rolling steel in modern times, and that the bars are supplied in the same rude form which was prevalent 50 years ago, thus ignoring the beautiful improvement which has been made in rolling steel; so that the forgers charge the same price for simply drawing down the tang upon a square or round bar of steel for a parallel or equalling file that they do for the entire forging of a half-round taper file blank of the same length.

Operations much more difficult than cutting files have been performed by machinery in various manufactures; amongst which may be named, as having taken its rise in this district, the combing of wool, in which by the manipulation of the machine itself the long fibres are selected and delivered into one compartment, and the short fibres into another; an operation which at first sight would appear to require an intelligent and discriminating power. The actual process of file cutting is however one of the simplest description. It consists in driving a chisel of suitable form and inclination to a small depth into the prepared surface of the blank, and steadily withdrawing it again; and cutting a file is merely a repetition of this operation. The difficulties to be surmounted are—to present the blank perfectly parallel to the cutting edge of the chisel: to withdraw the chisel from the incision made in the blank without damaging the edge of the newly raised tooth: to prevent a rebound of the chisel after the blow which drives it into the blank, and before the next blow is struck: to give a uniform traversing motion to the blank, ensuring regularity in the teeth: to proportion the intensity of the blow to the varying width of the file, so as to give a uniform depth of cut: and to perform these operations at such a speed as to make them commercially profitable. In most of the attempts that have been made to accomplish this process by machinery, the idea has been to construct an iron arm and hand to hold the chisel, and an iron hammer to strike the blow; and by this means to imitate as nearly as possible the operation of cutting by hand. The difference in the material used inevitably led to failure: the flexible and to some extent non-elastic nature of the fingers, wrist, and arm, enabled the man to hold the chisel, strike the blow, and then lift the chisel from the tooth, without vibration: not so when the iron hand and hammer are tried to perform the same operation; the vibration consequent upon the material employed frequently caused irregularity in the work and a ragged and uneven edge on the tooth. The slow speed at which these machines were worked rendered them unable to compete with hand labour.

In the machine forming the subject of the present paper the above objections have been nearly if not altogether obviated by an ingenious

modification in the mode of action. This machine is the invention of M. Bernot of Paris, and has been already working successfully for some time both in France and Belgium. The blow is given by the pressure of a flat steel spring pressing upon the top of a vertical slide, at the lower end of which the chisel is firmly fixed; the slide is actuated by a cam making about one thousand revolutions per minute, and the chisel consequently strikes that number of blows per minute, thus obviating the vibration consequent upon the blow with an iron mounted hammer, and moving at such a speed as to render any vibration impossible.

The accompanying drawings, Plates 27 to 30, show the various parts of a machine for cutting 18 inch bastard files, which is nearly the largest size required: for the smaller files, machines smaller in proportion are employed, down to one half the size of that shown in the drawings. Fig. 1, Plate 27, is a front elevation of the machine; Fig. 2, Plate 28, a vertical section taken at right angles to Fig. 1; and Fig. 3, Plate 29, a plan. In the front elevation, Fig. 1, some of the parts at the top of the machine which are behind the main framing are shown in front of it for the sake of distinctness, and a portion of the frame at the top is omitted for the same purpose; but the proper position of these parts is fully seen by a comparison with the vertical section and plan, Figs. 2 and 3.

The main shaft A, Figs. 1, 2, and 3, is mounted near the top of the framing, and is driven by a clutch that engages with a similar clutch on the boss of the driving pulley and flywheel B, which when the clutch is out of gear run loose upon the shaft; the clutch is moved by a hand lever with suitable notches to hold it in and out of gear, as shown in the plan, Fig. 3, Plate 29. The vertical slide C is lifted by a cam on the main shaft, and slides between adjustable V guides fixed in the frame of the machine, as shown in the plan, Fig. 3, Plate 29, and the enlarged plan, Fig. 11, Plate 30. The cutting chisel D, Fig. 2, Plate 28, shown black in the drawings, is held in a socket in the bottom of the vertical slide C and securely fixed by a set screw, as shown enlarged in Figs. 10 and 11, Plate 30. The blow is given by means of the horizontal flat spring E, Figs. 2 and 3, which is fixed at the outer end to a rocking shaft carried in a bracket at the back of the

main frame; this bracket also carries the pressure cam F pressing upon the middle of the spring and forming the fulcrum against which the spring is bent when the slide C is lifted by the cam on the shaft A, the spring being always in contact with the head of the slide C. The pressure of the spring and consequent depth of cut of the chisel is regulated by an adjusting screw at the outer end of the spring, Fig. 2; and in the case of cutting a parallel file this pressure is kept the same throughout. But in cutting a taper file the pressure is varied in the same proportion as the breadth of the file varies, so as to maintain an equal depth of cut throughout, by means of the pressure cam F being made to rotate during the traverse of the file; and the radius of the cam is made to increase and diminish in the proportion of the breadth of the file, thus varying the amount of deflection of the spring at each cut in the required proportion. The rotation of the cam is effected by means of the ratchet wheel G, Fig. 2, worked by an eccentric upon the main shaft A, Figs. 1 and 3, and thrown out of gear when a parallel file is being cut.

The file blank H to be cut, shown black in Figs. 1 and 2, Plates 27 and 28, is fixed upon a compound bed I, which admits of adjustment to any obliquity horizontally, as shown in the plan Fig. 3, by turning upon a strong centre pivot J in the bottom frame; and to any inclination vertically, as shown in Fig. 7, Plate 30, by rocking upon the centre bearing K, shown in the transverse section Fig. 8, Plate 30, which consists of a semicircular trunnion on each side of the file bed, as shown by the dotted lines in Fig. 7. The file bed is adjusted and secured at any required inclination by means of the circular arc L, Fig. 7, fixed to one of the pedestals M in which the file bed is carried. These two movements of the bed give the required obliquity of the chisel cut across the face of the file, and the inclination of the chisel to the plane of the file face; the chisel itself remaining always vertical. The trunnions K of the file bed are recessed into the two pedestals M, each supported by two pillars which are connected at the base by a turning plate N, turning on the centre pivot J. The upper end of this pivot is provided with a nut and washer to hold the turning plate N and secure the file bed I in the required oblique position.

The horizontal movement or traverse of the file between each cut of the chisel is given by means of a rack which slides in a longitudinal groove O in the file bed I, Figs. 2 and 3, Plates 28 and 29. This rack is advanced the required distance between each stroke of the chisel by the worm P, Fig. 2, the shaft of which has a ratchet wheel Q fixed on the outer end, as shown in Fig. 1, which is worked through a series of connecting rods and levers from the crank pin R upon the end of the main shaft A, Figs. 1 and 3. In order to provide for the double motion of adjustment of the file bed I, with an inclination both vertically and horizontally, this feed motion is communicated through a vertical spindle S, Fig. 2, passing up freely through the tubular centre pivot J upon which the file bed turns; the head of the spindle S is connected by a horizontal lever and connecting rod with swivel joints to the cranked rocking shaft T, which terminates at the centre line of the trunnions K on which the file bed rocks, as shown in the plan Fig. 3, and side elevation Fig 7: the other end of the rocking shaft T carries a paul that works the ratchet wheel Q on the shaft of the worm P, Fig. 1. The whole of this set of levers is carried by the turning plate N of the file bed, and turns freely upon the head of the centre spindle S without interfering with their action in driving the worm P.

The upper side of the file bed I is cut out in a semicircle, as shown in Fig. 1, Plate 27, and Fig. 8, Plate 30; and a moveable semicircular slide U, Fig. 2, which is of sufficient length to carry the file, is fitted into this semicircle so as to roll freely in the cavity. To the underside of this slide the rack O is attached by means of a groove and a cross piece, as shown in Figs. 2, 8, and 9. At each end of the slide U suitable fastenings V, Fig. 9, are attached for holding down the file, with levers, rack, and springs. A handle W, Fig. 2, with connecting rods, bell-crank levers, and springs, is mounted underneath the file bed I for disengaging the worm P from the rack O and allowing the slide U to be pushed freely endways, so as to bring it back easily after the file is cut. On the front of the main frame of the machine is mounted a leveller X, Figs. 1 and 2, shown enlarged in Figs. 10 and 11, for the purpose of pressing upon the file H and keeping it truly even with the edge of the chisel D; the upper end of

this leveller is jointed to a horizontal weighted lever Y, Fig. 1, one end of which is centred on the frame of the machine by means of a link joint, and the other end is weighted by a ball; a rest is provided for holding up the lever when required, as shown dotted in Fig. 1, so as to keep the leveller X clear of the file. Another lever Z, Fig. 1, is mounted upon a centre in the frame, for the purpose of raising the vertical slide C which carries the chisel, and is provided with notches to hold it in position.

Mode of action.—When the file bed I has been adjusted to the proper position, and the blank H to be cut fixed upon the semicircular slide U, the chisel slide C is lowered, so as to bring the edge of the chisel down upon the blank. The force of the main spring E then brings the surface of the blank perfectly even with the edge of the chisel D, in consequence of the rolling movement allowed by the semicircular slide U; in this position it is allowed to remain whilst the leveller X attached to the weighted lever Y is brought down upon the blank: a slot hole in the middle of the frame of the leveller X allows it to move so much as to bring its lower edge exactly parallel with the edge of the chisel and true to the surface of the blank, in which position it is then secured by hand by the tightening screw, as shown in Figs. 1 and 2. The blank is now slided along to the starting point, and the machine put in motion. If the blank to be cut is a taper flat file, the paul G which actuates the pressure cam F pressing upon the main spring E is put in gear, and the deeper side of the cam is gradually brought down upon the spring, causing it gradually to increase the pressure upon the chisel slide C and consequently increase the intensity of the blow until the chisel reaches the widest part of the file. When cutting a parallel or equalling file this apparatus is not required. After the file has traversed the length required to be cut, the driving clutch is thrown out of gear and the machine instantly stops; the chisel slide C is raised by the lever Z, the worm P disengaged from the rack O by the handle W, and the semicircular slide U drawn back; the file is then released and replaced by another, and the operation repeated. After the first cut has been completed, as shown full size in Fig. 6, Plate 29, the second cut is given in the contrary direction across the file, by turning the file bed I round to the

proper obliquity. Every description of round or half-round files is cut in this machine by the use of a revolving bed and dividing apparatus.

In regard to the durability of the cutting chisels in this machine, it is remarkable that they cut five times as many files as can be cut by hand without re-sharpening; and the reason seems to be that the chisel is driven into the blank and withdrawn again in a perfectly straight line and without any rubbing action; whereas in hand cutting, the fine edge of the chisel is rubbed a short distance along the surface of the blank until it comes in contact with the last raised tooth, which is the only guide the hand cutter has to produce regularity of cut. Fig. 4, Plate 29, shows a magnified diagram of the file teeth and chisel (as given in Holtzapffel's work) showing the action of the chisel in raising the teeth in hand cutting, and its inclined position; and Fig. 5 is a corresponding diagram of the chisel in this machine, showing the vertical position of the chisel and the inclination of the file travelling underneath it.

In the files cut by this machine the teeth are raised with perfect regularity, and consequently when the file is used each tooth performs its proper share of work; whereas in hand cutting, from the varying power of the muscles, especially towards the close of the day, it is impossible to produce such perfectly uniform work.

A manufactory employing twelve of these machines has been established at Douai in the north of France, and another at Brussels, in both of which the machines have been in successful operation for nearly two years.

Mr. GREENWOOD showed the machine in action, driven temporarily by hand power, and cutting several files with the first cut; a number of files completed by the machine were also shown.

The CHAIRMAN invited the members and their friends to join in the discussion upon the interesting and important subject of the paper that had been read, observing that the objects desired were the discussion of the mechanical questions involved, and the elucidation of facts of experience bearing upon the subject, without entering into any questions of priority of invention or patent claims.

Mr. B. FOTHERGILL thought the machine that had been shown displayed great ingenuity, and was very cleverly contrived for effecting the required object. A thoroughly efficient file-cutting machine had been long felt to be a great desideratum, and many attempts had been made at different times for the adaptation of machinery for that purpose; he remembered, when with Mr. Roberts in Manchester many years ago, an attempt was made by a firm in Sheffield to apply machinery to cutting files, but after many trials it was given up as not successful; and an unsuccessful attempt was also made by Ericsson. The mechanical difficulties of the operation had been to a great extent surmounted in the ingenious file-cutting machine that was shown at the Glasgow meeting of the Institution; and Mr. Preston of Manchester had subsequently constructed a machine that was now working with considerable success. Besides the mechanical difficulties in the application of machinery to cutting files, a very serious impediment was caused by the mistaken opposition of the workmen to the introduction of machinery; and this opposition was so determined that the machines had to be introduced into new districts in order to enable them to be worked. This was a most serious mistake on the part of the workmen, because no opposition could in the end prevent machinery from making its way wherever it was found capable of improving or economising any manufacture; and continued opposition of the workmen in any place could lead only to the trade being ultimately driven away to other more free and enlightened places, and many lamentable instances of this had already occurred in connexion with the textile and other manufactures in different parts of the country.

In cutting files by machinery special attention was required to the

peculiar form of tooth, so as to obtain a keen cutting tooth, and at the same time a form that was strong and durable, combined with complete uniformity so that the file might have an even bite over its whole surface. In hand-cutting files the workmen were very particular about the chisel being ground always to the exact angle that had been found best in long practice; and the exact upset or raising of the tooth was said to be given by a peculiar turn of the wrist at the instant of the blow, that would be difficult to effect satisfactorily by machinery. He enquired what extent of experience there had been of the working of the files cut by the present machine, and what were the results as to strength and durability of tooth; also what was the relative cost of machine-made and hand-made files in the regular course of work.

Mr. Greenwood replied they had no experience yet in England except of detached trials; but on the continent there was the experience of two years' regular working at Douai, and the result was that the entire cost of cutting 12 inch bastard files by the machine was only 4*d.* per dozen, instead of 32*d.* per dozen the lowest price for the same work by hand at Sheffield; there were 12 of the machines in operation together, all worked by one man with boys under him to attend the several machines. The machines were of different sizes according to the files to be cut; and the speed of those for the larger sized files was 900 to 1000 strokes per minute, cutting the surface once over in 35 seconds. There was thus an advantage of 8 to 1 in the cost of cutting by the machine; and the durability of the machine-cut files was also found to be greater than that of hand-cut files, from the more perfect regularity of cut, all the teeth sharing equally in the work and the teeth being raised so very regularly throughout; and the machine-cut files were preferred by the men for use, as they were found to bite equally all over.

In the machine the chisels were found to last much longer than in hand cutting, lasting generally for cutting five files before requiring sharpening, instead of requiring this with every file or oftener, as in hand cutting, on account of the cutting edge being worn by rubbing upon the surface of the file blank between each cut, the chisel being lifted over the raised edge of each cut directly after the blow and then drawn back on the surface of the blank to the other side of the raised

edge so as to give the position for the next cut, this being the only gauge by which the workman judged of the required distance; and the pitch of the cuts was thus proportioned to the depth of cut and corresponding height of tooth raised. In the machine the action of the chisel was simply a direct cut, and the chisel was instantly withdrawn without being subjected to any other wear; the cut could be regulated to the greatest accuracy, and he was satisfied that there was not any movement required in the process of file cutting that could not be perfectly effected by machinery.

The Chairman enquired whether any of the machines were in regular work in this country.

Mr. Greenwood replied that the machine shown was the only one at present in this country, and there were not yet any machines in regular work except those on the continent.

Mr. E. A. Cowper asked whether the machine could be used successfully for cutting round and half-round files, as there was greater difficulty in cutting those than in cutting flat files. He remembered Ericsson's file-cutting machine that had been referred to, having been engaged on the experiments that were tried with it; and the greatest difficulty experienced was with half-round files, from the liability of the file to shift sideways in the machine, causing the chisel to miss its fair blow. In the machine now shown there was an important improvement in the application of the chisel, which in Ericsson's machine was separate from the hammer and was arranged to accommodate itself to the file to be cut; but in the present machine the file was made to accommodate itself to the leveller, which was set exactly even with the chisel, and this was itself a fixture in the hammer; the vertical slide in which the chisel was firmly fixed was in effect the hammer, and would have to be made of suitable weight for the particular cut intended. In the files cut by the machine now shown the second cut seemed to be with the same force as the first cut: instead of which the general practice in hand-cut files he believed was to make the second cut lighter than the first, so as not to divide the first teeth completely down to the base, as the form of tooth then obtained was not so good, the first cut being thus partly closed up. The great regularity in the teeth of the machine-cut file was certainly an

advantage. The arrangement by which the force of blow was gradually reduced in a taper file was very complete; but the pitch of tooth remained uniform throughout, and he thought it would be an advantage if the pitch could be also diminished with the depth of cut.

Mr. Greenwood replied that there was no difficulty in cutting round files in the machine as well as flat files; the machines were of smaller size for this purpose, working at a speed as high as 1500 strokes per minute, and the tang of the file was fixed in a chuck like a lathe head, divided for the several cuts required in a complete revolution, so that the whole process was carried out completely without any difficulty. The force of blow was easily regulated with great exactness by the adjusting screw at the end of the spring: and it was a great advantage in the machine work that the depth of cut when once set continued the same throughout the work; instead of which in hand cutting there was unavoidably a gradual variation in the force of the blow from the fatigue of the workman's muscles towards the end of the day's work. The pitch of the teeth was at present kept uniform throughout in the machine, but it could be arranged to be varied if required, by adding a motion for changing the rate of feed; he did not think however that that was a point of any practical moment.

Mr. H. Maudslay thought the machine was very well designed and an ingenious arrangement of machinery for the purpose; it certainly did the work with great perfection and expedition, and appeared a highly successful attempt at accomplishing the difficult operation of cutting files by machinery. The difference in the cost of work as stated in comparison with hand cutting was very great, and he should be glad to know the whole expense of work, considering the outlay required for the machine.

The Chairman observed that when there was so great a difference as from 32*d.* to 4*d.* per dozen in the cost of labour in the manufacture, the expense of the machine would be of little consequence, since it would soon pay for itself if it did as good work.

Mr. B. Fothergill said he was acquainted with the working of machine-cut files, manufactured at Manchester, and they were found to be quite as good and durable as the best hand-cut files, if not superior; he was satisfied that the best class of files would ultimately be

manufactured by machinery, although the process might not be perfected at present. The machine now shown was admirably contrived for effecting some of the movements, particularly as regarded the moving pressure cam for varying the force of blow throughout the file, and the feed motion and disengaging apparatus for the rack. He hoped that others present who had tried to construct machinery for file cutting would give them the results of their experience.

Mr. J. Tomlinson had paid much attention to the subject for some time, but had found so many difficulties with taper and round files that he had lately given it up; however he would try again after witnessing the success attained in the ingenious machine now shown. He thought this was capable of improvement in some points, especially in reducing the violence of the blows, which he should be afraid would make the machine difficult to keep in good order; and though the machine did not yet appear quite perfect, he thought the object would still be accomplished. He enquired whether any greater difficulty was experienced in hardening the files cut by the present machine.

Mr. S. Greaves said he had been working the machine for several months and found it quite successful in cutting files, but it required to be managed by a man properly experienced in file cutting or it would not turn out good work: the machine might be made to work well or not according to the qualification of the man working it; but from his own experience in file manufacture for many years he was satisfied that the machine was capable of cutting perfect files in regular work. It could not be made to work properly when shown in a room, because the foundation was not solid and steady enough, which interfered with the perfection of cut. No difficulty was found in hardening the files, and they stood the process quite as well as hand-cut files.

Mr. E. A. Cowper observed that an important point in cutting files was to have them firmly and uniformly bedded on the machine throughout their entire length whilst receiving the blows of the chisel; and the arrangement in the present machine was an improvement in this respect: the leveller he thought a very good and expeditious contrivance for that purpose, allowing the chisel to come down upon the file with a thoroughly solid blow at each cut.

Mr. Greenwood said the file was laid upon a zinc bed in the machine, bedding flat throughout its whole surface; and after half a dozen files had been cut on the same bed, the machine was found to cut even better from the bed getting well fitted to the files. There was a little difficulty in first changing the machine from cutting one size of file to another, in order to get it into complete adjustment, and the best plan for regular work was to have machines of different sizes, keeping each one to a regular run of work; in such an arrangement, with a complete set of the machines, he was confident they would be kept at work for years together without any material cost for maintaining them.

The Chairman moved a vote of thanks to Mr. Greenwood for his paper, which was passed.

The following Paper was then read:—

ON THE RELATIVE ECONOMY AND DURABILITY OF VARIOUS CLASSES OF STATIONARY STEAM BOILERS.

By Mr. ROBERT B. LONGRIDGE, of Manchester.

The object of the present paper is to lay before the members of the Institution some statistics relating to Stationary Steam Boilers, showing the relative economy of the various classes of boilers usually employed for manufacturing purposes, and accompanying these statistics by remarks upon the advantages and imperfections peculiar to each class. The data here recorded and the opinions deduced are the result of many years' experience, during which the writer's position has afforded him unusual facilities for investigating this important subject: the boilers referred to in the following remarks exceed 1600 in number taken indiscriminately.

The following Table I, with the boilers divided into classes, shows the numerical ratio which these bear to each other, and may be considered a fair average of what are at present in use in the great manufacturing districts of Lancashire and Yorkshire:—

TABLE I.

Proportionate Number of different Boilers now working.

Wagon boilers	0·4	per cent.
Butterley boilers	2·6	"
Cylindrical boilers without internal flues	6·0	"
Cylindrical boilers with internal flues	75·0	"
Multiflued boilers	2·0	"
Galloway boilers	6·5	"
Multitubular boilers	7·5	"
	100·0	

This table shows that the class of boilers which have internal flues, commonly known as Cornish boilers, greatly preponderates, being no less than 75 per cent. of the whole. This proportion has reference to all boilers now working, and large as it may appear would be still

further augmented if reference were made only to those manufactured during the last two or three years, in which case the proportion of boilers with internal flues could not be estimated at less than 90 per cent. of the whole number of boilers made during that period. In consequence of this very large excess of one particular class of boiler, it will be well to enquire whether it arises from any decided superiority of boilers with internal flues, or merely from the habit of imitation which so generally prevails. Although these boilers do undoubtedly possess advantages over those which they have in a great measure superseded, it will be seen from the particulars given hereafter that they are inferior to other boilers of more recent introduction.

It has been found impossible to determine satisfactorily from the data which have been collected the correct relative economy of the several classes of boilers here referred to, inasmuch as the only common standard of comparison is the indicated horse power of the engines, which is evidently fallacious; for any difference in the degree of expansion of the steam used must affect the results, and in some cases to a great degree. Calculations based on such uncertain data must therefore be received with much caution; but as it may be of some interest to know the average consumption of fuel per indicated horse power in the manufacturing districts, this is given in Table II (appended), in which each class of boiler is distinguished, but no attempt is made to deduce any conclusions as to their comparative economy further than may be confirmed by individual experiments. Wherever boilers differing in construction have been working together it has been necessary to exclude these from the table; and as this is the case in a large proportion of factories, the number of boilers here referred to is comparatively small. Where the engines have not been indicated or the requisite particulars not obtained, the boilers have also been omitted. The following are the general results of Table II:—

	Average Indicated Horse power per boiler.	Average Consumption of Fuel per horse power per hour.
9 Butterley boilers	106	5·25 lbs.
8 Boilers without internal flues	39	8·36 ,,
476 Boilers with internal flues	120	4·85 ,,
14 Multiflued boilers	139	4·33 ,,
74 Galloway boilers	123	4·92 ,,
40 Multitubular boilers	170	3·46 ,,

Table III (appended) shows the evaporative duty of the various classes of boilers, as ascertained from experiments made with boilers working under their usual conditions. The general construction of the boilers experimented upon is shown in Plates 31 and 32, and they are distinguished in the Tables by the following letters of reference :—

A—Cylindrical boiler with 2 flues.			
B—	Ditto	ditto.	
C—	Ditto	ditto	shown in Figs. 1 and 2, Plate 31.
D—	Ditto	with 5 flues	shown in Figs. 3 and 4, Plate 31.
E—Multiflued boiler		with 7 flues	shown in Figs. 5 and 6, Plate 31.
F—Galloway boiler.			
G—	Ditto		shown in Figs. 7, 8, and 9, Plate 32.
H—Galloway Multitubular boiler			shown in Figs. 10 to 13, Plate 32.
I —Multitubular boiler			shown in Figs. 14 to 17, Plate 32.

In these experiments the fuel consumed was weighed, and the water evaporated was accurately measured by Kennedy's water meters, on the correctness of which great dependence may be placed from the high character they have deservedly acquired. The evaporative duty of the different boilers is given in Table III in lbs. of water evaporated from 62° Fahr. per lb. of fuel consumed; and a column is also added showing the equivalent quantity of water evaporated from 212° Fahr., for convenience of comparison with results calculated from the latter temperature. The following are the general results of Table III :—

Boiler experimented upon.		Pressure of Steam per square inch above atmosphere.	Water evaporated per lb. of Fuel from 62° Fahr.
A		20 lbs.	6·09 lbs.
B		40 ,,	5·95 ,,
C	1st exp.	55 ,,	7·48 ,,
	2nd ,,	49 ,,	6·88 ,,
D	1st exp.	32 ,,	6·16 ,,
	2nd ,,	39 ,,	6·16 ,,
E		40 ,,	7·41 ,,
F		32 ,,	7·35 ,,
G	1st exp.	40 ,,	7·25 ,,
	2nd ,,	40 ,,	7·48 ,,
H	1st exp.	51 ,,	8·03 ,,
	2nd ,,	48 ,,	7·71 ,,
I	1st exp.	60 ,,	8·36 ,,
	2nd ,,	60 ,,	7·82 ,,
	3rd ,,	60 ,,	8·08 ,,

The area of heating surface in the different boilers experimented upon is given in Table IV (appended) together with the area of firegrate; that only being reckoned as heating surface which can fairly be considered effective in generating steam. The following are the total areas in each case:—

Boiler.	Area of Firegrate.	Area of Heating Surface.
A	38 sq. ft.	590 sq. ft.
B	35 "	540 "
C	30 "	463 "
D	30 "	530 "
E	52 "	697 "
F	30 "	499 "
G	38½ "	898 "
H	30 "	599 "
I	30 "	454 "

In Table IV the several kinds or positions of heating surface are distinguished, not only as furnace and flue surfaces, but also as convex, concave, and vertical surfaces: for the value of any surface must depend much upon its position relative to the source of heat, the direction of the gases from the furnace, and the degree of circulation of the water in the boiler; or, in other words, upon the more or less favourable position of the surface for receiving or taking up the heat, and on the facility with which the heat is communicated by means of the circulation of the water. In the internal flues or tubes of boilers the deposit of dust and ashes from the fuel greatly retards the transmission of heat through the plates: on this account, and from the unfavourable position of the lower half of cylindrical flues and also of horizontal surfaces forming the underside of flues or combustion chambers, it has been usual to exclude these in estimating the area of heating surface, as is the case in the areas given in Table IV. From the frequent fracture of plates in these parts however, in consequence of overheating, it is evident that these surfaces do absorb and accumulate heat in sufficient amount to cause damage to the metal; by proper circulation of the water this might be prevented and steam generated, though possibly not to any practically useful extent. Upper horizontal surfaces, such as the crowns of square fireboxes and combustion chambers, have hitherto been generally considered the most

effective. This seems however to be exceedingly questionable, particularly with regard to horizontal surfaces of large extent: for a surface can only be relatively effective in proportion to the rapidity with which the communicated heat can be carried off by the water; and the maximum of efficiency will be attained when no accumulation of heat takes place in the plates, which must depend entirely on the circulation of the water. There can be no question that horizontal surfaces are the best to absorb heat; but unless the heat be carried off by the water and prevented from accumulating in the plates, the practical value of the surface for generating steam will be much impaired and the plates speedily injured: hence those surfaces are to be preferred, which combined with naturally good positions for absorbing heat offer also the greatest facility for circulation of the water. Since in the case of horizontal surfaces, particularly of large extent, the currents of water tending towards the middle from the outside or from above, can reach the middle only by opposing the ascending currents of steam and water, they must of necessity be more or less diverted from their course; and the circulation being thus interrupted, not only will the generation of steam be less than the surfaces are capable of producing, but as a necessary and more serious consequence the plates must be subjected to constant overheating, and sooner or later will become deformed and seriously injured. Under these circumstances an accumulation of deposit usually takes place, which has been assigned as the cause of the injuries and fractures of the plates, where these have occurred; though in reality the presence of deposit affords evidence only of comparative quiescence or imperfect circulation of the water at these parts, of which it is the effect. On this account therefore upper horizontal surfaces, especially when of large extent, cannot be the most effective, nor even so effective as has generally been supposed; indeed when exposed to the direct action of the fire they are in many cases objectionable. Surfaces concave towards the fire and heated gases, and flat surfaces deviating somewhat from the perpendicular, are probably the most effective; for from these the steam will rise freely and the water will be brought more readily in contact with the plates, the surfaces being in a position more favourable for circulation; provided only that the water spaces are not too con-

fined, a fault to be found frequently in locomotive and marine boilers. These remarks will suffice to explain the writer's object in making a distinction in the kinds of heating surface in the boilers experimented upon; and he would express a hope that this important question may be made the subject of further investigation.

The following are the particulars of the experiments given in Table III :—

A—*Cylindrical boiler with 2 flues.* Each trial with this boiler continued during a whole week of 60 working hours. The fuel consumed included that required for raising steam every morning. The evaporation per lb. of fuel is therefore less than would have been the case, had each trial extended over only 6 or 7 hours, as in some of the other experiments.

B—*Cylindrical boiler with 2 flues.* This experiment also extended over four working days, under similar circumstances to the preceding.

C—*Cylindrical boiler with 2 flues*, shown in Figs. 1 and 2, Plate 31. This boiler having worked only a few weeks was free from scale, which should be borne in mind in comparing it with the other boilers. In the first experiment the mean of two trials of 12 hours each is given. The temperature in the main flue leading to the chimney averaged 548° Fahr. as measured by Gauntlett's pyrometer, and the evaporation was 7·48 lbs. of water per lb. of fuel. Comparing this with the first experiment with the Galloway multitubular boiler H, shown in Figs. 10 to 13, Plate 32, which was also new and free from scale and tried under precisely similar conditions, it will be observed that the evaporation is 8·03 lbs. of water per lb. of fuel or nearly 7½ per cent. greater with the latter, while the temperature in the main flue was only 416° Fahr.; showing that a larger portion of the heat had been abstracted from the gases during their passage through the flues in the Galloway multitubular boiler, owing to the larger area and more particularly to the better description of heating surface. A second experiment with the cylindrical two-flued boiler C shows the evaporation in the course of 48 successive hours, the rate of combustion during the night being only about one half of that during the day. The evaporation is considerably less than in the

first experiment, amounting to only 6·88 lbs. of water per lb. of fuel, probably owing to the fires having been neglected, an excess of air passing through the grate where not covered with fuel. A corresponding second experiment with the Galloway multitubular boiler H shows a similar result, the evaporation being diminished to 7·71 lbs. of water per lb. of fuel; but in this case also the superiority of the same boiler is exhibited by an increased evaporation of 12 per cent. over the boiler C. In this instance there has been an excellent opportunity for comparison, each of the boilers compared having been worked on the same premises under the conditions best suited to them.

D—*Cylindrical boiler with* 5 *flues*, shown in Figs. 3 and 4, Plate 31. This boiler with an external furnace gave anything but a satisfactory result, the evaporation being only 6·16 lbs. of water per lb. of fuel. Various alterations were then made in the size of firegrate, the mode of setting, and the admission of air, in order to effect perfect combustion of the fuel; but although this seemed to be attained, the evaporative power could not be increased, as shown in the second experiment given in the table. Comparing this with an old Galloway boiler F, working under similar conditions, a marked difference is apparent, the evaporation per lb. of fuel being 7·35 lbs. of water or nearly 20 per cent. higher with the latter.

E—*Multiflued boiler with* 7 *flues*, shown in Figs. 5 and 6, Plate 31. The evaporation in this boiler was 7·41 lbs. of water per lb. of fuel, or nearly the same as that obtained in the first experiment with the new cylindrical two-flued boiler C; but the evaporation per square foot of grate per hour was 8 per cent. greater with the multiflued boiler, the grate surface of which was 73 per cent. larger and the total effective heating surface 50 per cent. larger than in the boiler C, as shown in Table IV. The relative values of the fuel used in the two cases not having been ascertained, a fair comparison can scarcely be drawn; but it is probable that the advantage would be on the side of the multiflued boiler E.

F—*Galloway boiler;* has been already referred to and compared with the cylindrical five-flued boiler D.

G—*Galloway boiler*, shown in Figs. 7, 8, and 9, Plate 32. In the first experiment with this boiler when burning slack of a very

inferior quality, the evaporation was 7·25 lbs. of water per lb. of fuel or 3 per cent. less than in the first experiment with the new cylindrical two-flued boiler C; but in a second experiment with a better quality of fuel the evaporative duty appears to be equal in the two boilers. The boiler G having worked for many years, its evaporative power would to some extent be impaired by incrustation on the plates; but as regards the rate of evaporation per square foot of grate per hour it stands much higher than any other boiler in the table.

H—*Galloway Multitubular boiler*, shown in Figs. 10 to 13, Plate 32. This boiler has been already compared with the new cylindrical two-flued boiler C, and its superior evaporative duty is also apparent as compared with the preceding Galloway boiler G.

I—*Multitubular boiler*, shown in Figs. 14 to 17, Plate 32. In the first experiment this boiler appears to surpass all the preceding in evaporative duty, the evaporation being 8·36 lbs. of water per lb. of fuel; but as the coal here used was of a much better quality, probably the best steam coal in Lancashire, the superiority of this boiler may not be so great as would at first appear. The construction is undoubtedly good; but seeing that the Galloway multitubular boiler H with a much inferior quality of fuel falls little short in evaporative duty, it is probable that with the same quality of fuel the latter would give the higher evaporative duty. On the other hand it must be observed that the rate of evaporation per square foot of grate per hour is considerably higher in the multitubular boiler I. The second and third experiments with this boiler show the evaporative duty during two consecutive weeks: these may be compared with the weekly results of the cylindrical two-flued boiler A, over which they exhibit a marked superiority, the conditions of the experiments being similar in the two cases, excepting in regard to pressure of steam and quality of fuel as already mentioned.

The relative economy of the various classes of boilers as regards evaporation of water and consumption of fuel having thus been shown, the next question to be considered is their relative durability and the defects peculiar to each.

The *Wagon boiler* is now rapidly disappearing from Lancashire and Yorkshire, being unsuited for the increased pressure of steam which has of late years been generally employed. It is therefore scarcely necessary to refer to this construction of boiler, excepting to remark that in the concave surface exposed to the fire and the vertical curved surfaces of the sides a very effective kind of heating surface is presented. The bottom of the boiler where it rests on the seating is the part where repairs are most frequently required, owing principally to imperfect circulation of the water at that part, resulting in fracture or leakage and corrosion of the plates.

The *Butterley boiler*, similar in form at the furnace, is liable to the same defect; but for a moderate pressure is decidedly to be preferred to the cylindrical boiler without flues.

The chief merits of the *Cylindrical boiler without flues* consist in great strength and simplicity of construction and in its being suited to rough usage; but as regards economy in fuel little can be said in its favour. On this account it has been principally confined to collieries and ironworks, where economy in fuel is generally too little regarded. The chief defect to be attributed to this class of boiler is fracture of the plates over the fire; but this is frequently much aggravated from an error in setting, too little height being allowed between the underside of the boiler and the firegrate or at the bridge, under which circumstances even the best plates will not long escape injury from the intensity of the fire. Various combinations of the plain cylindrical boiler have been introduced, with a view to increased economy, but very partial success has attended these endeavours: amongst them may be mentioned Woolf's and the French boiler and others of more recent date. These however appear to possess few merits to recommend them; and it may be unnecessary to allude to them further than to observe that in the French boiler a large area of heating surface is presented, nearly the whole of the lower vessels containing the water being exposed to the flame or heated gases. But it is evident that in this arrangement the circulation of the water must be exceedingly defective, there being only two or three connecting pipes to serve as a communication between the upper and lower vessels: the steam generated in the latter not finding ready means of exit accumulates and allows the

plates at the top to become overheated and fractured from non-contact of the water; while fractures occur also at the bottom in consequence of insufficient circulation of water, thus rendering frequent and expensive repairs necessary. There is moreover great liability to priming, owing to the obstruction offered to the escape of steam from the lower vessels: it has been observed in the working of these boilers that, instead of a regular ascending current of steam, its ascent from the lower vessels is intermittent, and much water is carried along with it. To remedy this defect, plates or pipes have in some instances been introduced to separate the ascending and descending currents; but even then the results have not been satisfactory, and this boiler though still extensively used in France is but little adopted in this country.

The *Cornish boiler or cylindrical boiler with internal flues* is, as has been shown in Table I, by far the most common form of boiler in Lancashire and Yorkshire. It is simple in construction, affording great facility for cleaning and repairs; but on the other hand possesses serious defects, the principal of which are imperfect circulation of water and weakness of the flues: the former being the cause of unequal expansion in the boiler, producing straining of the seams and sometimes fracture of the plates; and the latter being the most frequent source of explosion. With fires in the flues, the smaller the flue the greater is its strength; but the more imperfect is also the combustion, owing to the cooling effect of the plates upon the fuel and the gases. With large flues, it will be seen that the spaces S S, Fig. 2, Plate 31, between the boiler shell and flues, being necessarily small, the ascending currents from the upper part of the flues exposed to the action of the fire and from the flue surfaces of the shell must greatly impede the flow of the downward current, and in some cases when very narrow almost entirely prevent it: consequently the difference of temperature between the upper and under side of the boiler will be considerable, especially when first raising steam; the effects of which are unequal expansion, leakage at the seams, and not unfrequently fracture of the plates near the centre at the under side. Another defect common to this boiler is the fracture of the end plates or angle iron rings by which the flues are attached. This appears to be caused by the repeated alternate strains to which these parts are

subjected: when the boiler is empty it is strained by the weight of the flues, if they are supported only at the ends; and when at work by the reverse strain due to the buoyant action of the water upon the flues and the pressure upon the ends. To remedy this some makers have adopted the plan of supporting the flues in the middle by means of a plate stay attached by angle iron to the flues and to the shell, an arrangement which has of late become more general, since it has been shown by some recent experiments made by Mr. Fairbairn and the writer that the strength of flues varies nearly in the inverse ratio to their length. The most efficient mode of strengthening such flues is however by the adoption of Adamson's plan of flanged seams, as shown in Fig. 17, Plate 32. Beyond the fact above stated, that within certain limits the strength of cylindrical flues varies inversely as their length, little is known on this subject. The ultimate strength of flues still remains a matter of uncertainty; for while some flues 3 feet diameter made of ⅜ inch plates and exceeding 30 feet in length have continued working for years at a pressure of not less than 65 lbs. per square inch above the atmosphere, others of smaller diameter and equal thickness but shorter length, and therefore supposed to be of greater strength, have collapsed apparently at a lower pressure. The experiments already made on this subject have certainly been of some service, but are by no means conclusive as to the absolute strength of flues, especially if there be any deviation from the cylindrical form.

The *Multiflued boiler* may be considered an intermediate stage between the Cornish and the multitubular boiler, and has the advantage of being stronger in the flues and probably more economical in fuel than the former.

The *Galloway boiler* is in one respect superior to all the other boilers mentioned: namely in having better circulation of the water by means of the vertical pipes in the flues, the heat being carried off as rapidly as received by these surfaces, against which the heated gases impinge. An equality of temperature consequently prevails throughout the whole body of the water, and a boiler of this construction is therefore not subjected to the severe strains produced by unequal expansion, which so frequently cause leakage and fracture in the under side of Cornish and multitubular boilers. In economy of fuel it has

already been shown that this boiler holds a high position, which appears to be mainly due to the large proportion of nearly vertical heating surface, and the more perfect circulation of the water. Objections have been raised against the oval flue on the ground of weakness of construction; but with the water pipes as stays sufficient strength is obtained for moderately high pressure, and by the adoption of the plan of flanged seams before mentioned the strength could be increased beyond any present requirements.

The *Multitubular boiler*, though universally admitted to be economical in fuel, has generally fallen into disrepute, in consequence of the frequent repairs required, and the difficulty or impossibility of cleaning properly where there is much sediment from the water. Where set without external flues, leakage on the underside and consequent corrosion of the plates have usually taken place. This however has been to some extent remedied by constructing a return flue underneath, so as to maintain more nearly an equality of temperature throughout the boiler; the cause of failure being as already explained the unequal expansion of the upper and lower parts of the boiler from want of proper circulation of the water. Owing to the difficulty of removing sediment in this boiler, a solid mass is formed in the course of time, preventing access of the water to the tubes and thus seriously impairing their efficiency and durability. Tubes generally have been made unnecessarily long, a considerable portion of their length being of little if any value for generating steam: for the gases on entering a tube, having imparted a large portion of their heat to the surface with which they first come in contact, continue in their comparatively cooled state in contact with the tube, preventing in a great measure the transmission of heat from the hotter gases in the centre of the tube. On this account in several multitubular boilers of recent make the length of the tubes has been considerably reduced, and with decided advantage. In the Galloway multitubular boiler the small tubes are very short, not exceeding 3 feet in length.

The writer has not thought it necessary in this paper to enter upon the question of combustion though intimately connected with that of economy of fuel, that part of the subject having been so fully discussed

by others. In the experiments above detailed no particular attention was directed to the question of smoke: the usual mode of firing was followed, and there was no great emission of smoke, the air being partially admitted through the firedoors, except in the Galloway boiler G, where it entered entirely through the grate; but the combustion cannot be said to have been perfect, nor therefore do the tables here given show the absolute value of the fuel used.

There is no doubt that great as has been the progress of late years in the construction of steam engines and the economical use of steam by working expansively, this has not been accompanied by equal progress in the construction of steam boilers; for whatever may be the scientific knowledge in the latter branch of engineering it certainly is not favourably exhibited in the generality of boilers in present use. On the contrary the laws of combustion and evaporation seem generally to have been almost entirely ignored, and waste of fuel and rapid deterioration of boilers have been the natural consequences. In concluding these remarks the writer would express a hope that, imperfectly as this subject has been treated, sufficient has been said to show the necessity of further investigations, and to induce other members of the Institution to prosecute these enquiries, which cannot fail to prove of great practical value to the manufacturing community.

TABLE II.

Consumption of Fuel in different Boilers.

Description of Boiler.	Pressure of Steam per square inch above atmosphere.	Number of Boilers.	Indicated Horse power of Engines.	Average Horse power per Boiler.	Average Consumption of Fuel. Per Boiler per hour.	Per Horse power per hour.
	Lbs. Lbs.		H. P.	H. P.	Lbs.	Lbs.
Butterley Boilers.	up to 15	2	204	102	518	5·08
	16 to 30	7	749	107	567	5·30
	Totals ...	**9**	**953**	**106**	**556**	**5·25**
Boilers without internal flues.	16 to 30	4	165	41	307	7·49
	31 to 45	4	149	37	345	9·32
	Totals ...	**8**	**314**	**39**	**326**	**8·36**
Boilers with internal flues.	up to 15	23	2102	91	479	5·26
	16 to 30	208	22779	110	580	5·27
	31 to 45	131	15303	117	582	4·98
	46 to 60	78	10983	141	595	4·22
	above 60	36	5923	165	634	3·84
	Totals ...	**476**	**57090**	**120**	**582**	**4·85**
Multiflued Boilers.	16 to 30	1	69	69	446	6·46
	31 to 45	8	816	102	531	5·21
	46 to 60	5	1056	211	748	3·55
	Totals ...	**14**	**1941**	**139**	**602**	**4·33**
Galloway Boilers.	16 to 30	29	3248	112	644	5·75
	31 to 45	31	3960	128	578	4·52
	46 to 60	14	1863	133	582	4·38
	Totals ...	**74**	**9071**	**123**	**605**	**4·92**
Multitubular Boilers.	up to 15	2	162	81	614	7·58
	16 to 30	1	162	162	1039	6·41
	31 to 45	16	2406	150	482	3·21
	46 to 60	21	4064	194	647	3·34
	Totals ...	**40**	**6794**	**170**	**589**	**3·46**

TABLE III.

Evaporative Duty of different Boilers.

Boiler experimented upon.	No. of trials.	Length of trials.	Pressure of Steam per sq. in. above atm.	Area of Fire-grate.	Fuel consumed. Per hour.	Fuel consumed. Per sq. ft. of grate per hour.	Water evaporated. From 62° Fahr. Per hour.	Water evaporated. From 62° Fahr. Per sq. ft. of grate per hour.	Water evaporated. Per lb. of Fuel. From 62° Fahr.	Water evaporated. Per lb. of Fuel. From 212° Fahr.	Description of Fuel.
		Hours.	Lbs.	Sq. Ft.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	
A	2	120	20	38	688	18·1	4193	110·3	6·09	7·02	Burgey of good quality;
B	1	40	40	35	717	20·5	4269	122·0	5·95	6·86	Plodder Mine, Lancashire.
C 1st exp.	2	24	55	30	355	11·8	2656	88·5	7·48	8·61	Slack of good quality;
C 2nd „	1	48	49	30	272	9·1	1871	62·4	6·88	7·92	Schofield Hall, Lancashire.
D 1st exp.	5	32	32	30	613	20·4	3777	125·9	6·16	7·09	Burgey of average quality;
D 2nd „	8	47	39	30	655	21·8	4035	134·5	6·16	7·09	West Leigh, Lancashire.
E	16	56	40	52	670	12·9	4964	95·5	7·41	8·53	Burgey of good quality; Duckworth Hall, Lanc.
F	3	21	32	30	512	17·1	3765	125·5	7·35	8·47	Burgey of average quality; West Leigh, Lanc.
G 1st exp.	2	21	40	38½	917	23·8	6648	172·7	7·25	8·35	Slack of inferior quality; Yorkshire.
G 2nd „	1	10½	40	38½	896	23·2	6702	174·1	7·48	8·61	Burgey of good quality; Yorkshire.
H 1st exp.	2	24	51	30	357	11·9	2865	95·5	8·03	9·24	Slack of good quality;
H 2nd „	1	48	48	30	275	9·2	2119	70·6	7·71	8·88	Schofield Hall, Lancashire.
I 1st exp.	2	7½	60	30	450	15·0	3762	125·4	8·36	9·62	Burgey of very good quality;
I 2nd „	1	72	60	30	468	15·6	3659	122·0	7·82	9·00	Oldham Black Mine,
I 3rd „	1	67	60	30	462	15·4	3733	124·4	8·08	9·30	Lancashire.

A,B,C—Cylindrical boilers with 2 flues; D—Cylindrical with 5 flues; E—Multiflued with 7 flues; F,G—Galloway; H—Galloway Multitubular; I—Multitubular.

TABLE IV.

Area of Heating Surface in different Boilers.

Boiler experimented upon.	Dimensions of Boiler.				Area of Firegrate.	Area of Heating Surface.					
	Length.		Diameter.			In Furnaces.		In Flues.			Total Area.
						Concave.	Convex.	Concave.	Convex.	Vertical.	
	Ft.	Ins.	Ft.	Ins.	Sq. Ft.	Sq. Ft.	Sq. Ft.	Sq. Ft.	Sq. Ft.	Sq. Ft.	Sq. Ft.
A	28	0	8	6	38	90	...	207	280	13	590
B	28	0	7	6	35	84	...	194	250	12	540
C	26	0	6	6	30	72	...	154	227	10	463
D	18	0	8	3	30	...	98	252	157	23	530
E	29	6	7	6	52	110	...	220	324	43	697
F	22	0	7	2	30	70	...	93	241	95	499
G	30	0	7	0	38½	88	...	288	315	207	898
H	26	0	6	6	30	72	...	230	227	70	599
I	30	0	6	6	30	64	...	380	...	10	454

A, B, C—Cylindrical boilers with 2 flues; D—Cylindrical with 5 flues; E—Multiflued with 7 flues; F, G—Galloway; H—Galloway Multitubular; I—Multitubular.

Mr. Longridge said his object in the paper had been to give the general result of a very large number of observations upon the working of steam boilers that had come under his inspection in connexion with the Boiler Association in Manchester and the neighbourhood, in order to derive from them as far as practicable some general conclusions respecting the relative economy and durability of the different constructions of stationary boilers in most extensive use. An important question involved was which kind of heating surface proved the most efficient on the whole; and this appeared to be not yet cleared up, as several different considerations were connected with it. In some cases owing to great facility for the escape of steam from the surface where it was generated a good result was obtained in evaporative duty, although the heating surface was really of inferior form for absorbing heat: he was inclined to think that the tube-plate in a multitubular boiler evaporated nearly as much water as the tubes, in consequence of the imperfect means of escape for the steam from the surface of the tubes.

He wished to call attention more particularly to the Galloway multitubular boiler shown in Figs. 10 to 13, Plate 32, in which the temperature of the smokebox proved to be 132° lower than in the cylindrical two-flued boiler compared with it, shown in Figs. 1 and 2, Plate 31; the temperature being only 416° in the former instead of 548° in the latter, showing a much more complete absorption of the heat by the former boiler. In this experiment the circumstances were exactly the same with both boilers, so that they could be correctly compared: the result was that 7·48 lbs. of water were evaporated per lb. of fuel by the cylindrical two-flued boiler, whilst the Galloway multitubular boiler evaporated 8·03 lbs. of water per lb. of fuel, giving 7½ per cent. more duty.

The Chairman remarked that the object to be attained was the highest evaporative duty in the smallest space combined with the greatest durability of the boiler, and the great difficulty in boilers was to obtain these several advantages without unduly sacrificing any essential point. The maintenance of a good circulation in the water was one of the most important means of obtaining durability of the boiler, by preventing inequality of temperature in different portions;

and in some of the long boilers with double flues there was no chance of circulation of the water on account of the narrowness of the water spaces, unless by the water descending at the back end and rising at the front end.

Mr. Longridge said that proper circulation of the water in the boiler was certainly the point of greatest importance, and the fractures in the bottom of boilers would be much less likely to occur if this were sufficiently attended to. The spaces were so small in some boilers that no effective circulation of the water could take place in them, being frequently only 3 inches wide in two-flued boilers; he had known boilers of that kind 30 feet long which worked for half a day before the water at the bottom became heated to the temperature of the steam, and this inevitably led to fracture of the bottom plates from the strain of unequal expansion.

Mr. J. Kitson thought the paper that had been read was of great value, especially in that district, where so many boilers were at work, and where sufficient attention was not paid in many cases to the important question of durability of the boilers as well as economy of fuel. The consideration of durability as affected by the mode of construction and setting of boilers had he believed been much disregarded in proportion to its importance, probably in consequence of the apparent commercial value being too exclusively considered in the first instance. The improvement of boilers would he thought be materially interfered with and retarded, so long as they were paid for according to the usual practice at a rate per ton; and it would be impossible that boilers economical in arrangement of material and consumption of fuel and of scientific excellence should prevail unless a different system were adopted. Nothing was more fallacious than the idea of cheap boilers, taking simply first cost into consideration; the principle of construction of boilers greatly affected their durability and the profit to be got out of them by the persons using them, and the question of first cost became but a minor consideration in comparison with the durability and cost of future maintenance and repair. He hoped that a change in the mode of charging for boilers would be made before long, placing this question on a more correct basis than the present plan, and he did not think there would be any serious commercial difficulty in making the change.

The paper that had been read was of particular value, as a record of results derived from the extensive experience of the writer in the inspection of a very large number of boilers; and these results afforded valuable data for a comparison between the different kinds of boilers as to their permanent economy. He thought the form of boiler that had been specially pointed out in the paper as giving the best results appeared rather more complicated than he should have preferred; for simplicity of construction was a very important consideration in respect of diminishing the expense and delay of repairs.

Mr. B. GOODFELLOW observed that in making comparative trials of the evaporative capabilities of boilers particular care was requisite to ascertain the quantity of water actually evaporated, free from any loss of water by other causes; as well as to ensure exact correspondence in the circumstances of the boilers, not only as to quality of fuel, but also to have the same draught and the same management of the fire. It was very difficult on this account to arrive at the true result; and he had known some double-flue boilers that appeared to be giving much less evaporative duty than others although similar in construction. In respect of the circulation of the water in boilers, he had been led to think it not so imperfect as seemed to be supposed; he had made an experiment by inserting a short pipe 6 inches long into the end of a two-flued boiler underneath the flues near the bottom, and a similar pipe 7 feet long close to it, each pipe being closed by a cock. He found that the temperature of the water from the shorter pipe, which was 80° at starting to raise the steam, rose 10° when the steam was up; but the water from the longer pipe had risen 23° in the same time, showing that the heat was steadily moving through the water though slowly.

The CHAIRMAN remarked that the only true comparison of the efficiency of boilers was the measurement of the water actually evaporated with the same fuel; and no correct data could be obtained from the comparison of the indicated horse power that was often made for the purpose, since in that case the boiler and engine were coupled together, and the effective value of neither of them could be ascertained; for it might be a good boiler coupled to a bad engine or the reverse, and the results obtained were unavoidably more or less fallacious from that

circumstance. The object to be aimed at was to obtain the form of boiler that best combined the advantages of economy in consumption of fuel with durability and economy in repairs and compactness of the space occupied; the latter points were of great importance in marine boilers and many cases of stationary engines.

Mr. W. E. Carrett considered the ordinary custom of purchasing boilers by weight without reference to construction was a great disadvantage, and led to the use of inferior forms of boilers. He suggested that in the Galloway multitubular boiler which had been referred to it might be advantageous to place the tubes in a separate chamber containing the feed water, so as more effectually to take up the remaining heat of the flue before reaching the chimney; and he enquired whether such a plan was not found to be economical.

Mr. Longridge replied that in stationary boilers, although there was an advantage to be gained theoretically by heating the feed with the waste heat of the flue, yet he had found the plan was generally abandoned on account of the accumulation of soot upon the heating apparatus, which so greatly impaired its efficiency as to make it not worth the additional complication. An exception to this was Mr. Green's apparatus, in which the surface of the heating pipes was kept free from deposit of soot by the continued action of scrapers moved slowly up and down the pipes by means of machinery; this apparatus was certainly very efficient and produced an important economy in the consumption of fuel.

The Chairman observed that this plan amounted in effect to increasing the heating surface of the boiler, by applying some additional surface that was maintained in an efficient condition for absorbing heat; and whatever construction of boiler might be adopted, the object would be to leave as little waste heat as practicable to pass away unabsorbed by the water.

Mr. S. Bastow thought the subject of the paper read was a very important one for discussion, and the paper was one of much value for the practical information and results contained in it. The question was one that was materially affected by locality, for the relative cost and quality of fuel made a great difference in the comparative value of economy in consumption of fuel as one of the objects to be aimed

at in a boiler; where fuel was cheap and economy of space was also not of importance, a simple and cheap make of boiler that was safe and durable would be preferable. In the iron districts of the north, plain cylindrical boilers with convex ends were much used, as they were found very durable and cheap in manufacture, and these were points of greater importance there than economy in consumption of fuel; the boilers were generally of great length, 50 to 100 feet long, and about 4½ feet diameter, set with a "flash flue," a single flue open to the entire underside of the boiler. But wherever fuel was not very cheap, it was undoubtedly the right course to seek for the most economical form of boiler as to consumption; it was then the best plan commercially to give a larger sum for the boiler in the first instance so as to obtain a more perfect construction, and this would prove a great saving in the end.

The CHAIRMAN moved a vote of thanks to Mr. Longridge for his paper, which was passed.

The following Paper was then read:—

DESCRIPTION OF A DIRECT-ACTING STEAM CRANE.

By Mr. ROBERT MORRISON, of Newcastle-on-Tyne.

The advantages of being able to remove heavy weights with facility at the lowest possible cost and in the shortest time are of great importance in many cases, such as in dock and warehouse work &c.: but the general principle of steam cranes, constructed simply as ordinary cranes with a couple of cylinders attached to drive the gearing in place of manual labour, makes them open to objection from their complication, since they are not well adapted for the expedition now required in discharging cargoes, in consequence of the great wear and tear upon them and the frequent chances of accident from the breaking of a tooth in the wheels or a link in the chain; also on board ship the rattling and shaking caused by the working of such cranes is found to be injurious to the decks. The writer has for some time endeavoured to substitute a machine that would perform all the work of a steam crane efficiently with the least possible amount of manual labour in the shortest time, and also be composed of the smallest number of parts. The result has been the Direct-Acting Steam Crane forming the subject of the present paper, in which the steam cylinders, gearing, and other complications of the ordinary steam crane are done away with; and the crane post itself is made the steam cylinder, fitted with a piston having a flexible piston rod of wire rope, which works steam-tight through a stuffing-box at the top and passes over two pulleys, forming itself the chain for lifting the load.

The new steam crane is shown in Fig. 1, Plate 33, which is a side elevation of a 2½ ton crane that has been at work for the last 14 months on the quay at the writer's works, Newcastle-on-Tyne. Fig. 2, Plate 34, is a vertical section of the crane post to a larger scale; and Fig. 5, Plate 35, a sectional plan.

The crane post or cylinder A of cast or malleable iron is made in one length, or in two or more pieces bolted together as may be convenient, and bored out to a size suitable for the weight to be lifted and the pressure of steam to be used. The length of the bored portion of the crane post corresponds with the height of lift required. Within the cylinder works the piston B which is firmly secured to the end of the flexible piston rod or wire rope C. This piston is made with a wedge-shaped packing ring, as shown in the enlarged section, Fig. 7, Plate 35, so that when the pressure of steam is upon it the packing expands and makes it steam-tight; but as soon as the pressure is removed the packing contracts, so that the piston works freely in the cylinder and the weight of the rope is sufficient to overhaul it. The wire rope C works steam-tight through a stuffing-box D at the top of the crane post, and passes over the two pulleys, one on the top of the crane post and the other at the extremity of the jib. At the end of the rope is fixed the cast iron ball E, containing a volute spring to which the hook is attached for the purpose of relieving the crane and rope from any abrupt strain when beginning to lift the weight. The wire rope is much safer than a chain, since it is not liable to the sudden fracture often occurring in crane chains, nor is it affected to the same degree by the temperature of the atmosphere. The rope used in the crane at the writer's works is made of steel wire; it is 1 inch in diameter and would carry 10 tons, and is sufficiently flexible for all purposes. The stuffing-box D through which the wire rope works is fitted with a conical gland, pressed down by a spiral spring, so that the packing is always kept well pressed up round the wire rope, without the necessity of screwing up as is the case with ordinary stuffing-boxes. The turning round cylinder F, Figs. 2 and 5, for swinging the crane round, is cast on the underside of the bed plate G and forms part of it; it is truly bored and fitted with a rectangular metal-packed disc or radial piston H secured to the outside of the crane post A. A segmental block I forming the abutment is bolted to the inside of the cylinder F, and made steam-tight next the crane post by metallic packing and springs.

In working the crane, the steam is admitted from the steam pipe K through the lifting valve L by means of the handle, Fig. 4,

Plate 34, and passes up through the port M in the crane post A, Figs. 2 and 3, to the top of the post, where it presses on the lifting piston B and raises the load. The valve L is then closed, and the steam retained in the cylinder A so as to hold the weight suspended; while the crane is swung round right or left by admitting steam through the turning valve N to either side of the turning piston H. The handle L is then reversed and the steam above the piston B allowed to escape through the exhaust pipe O, and the weight is lowered to the required position fast or slow as desired. There is a passage round the stuffing-box P for the purpose of admitting the steam into the port M at any position of the crane; this passage is packed at top and bottom with a lantern brass between, so that the top gland tightens both packings at the same time. It was apprehended at first that on account of the expansive action of the steam there would be some difficulty in starting and stopping the crane instantaneously: but no such difficulty exists in practice. The lifting valve L shown enlarged in Figs. 8 and 9, Plate 35, is made with oblique edges, so that the lifting can begin gradually and stop instantly. The turning round valve N is also made in the same way; and for stopping the crane suddenly when turning round it is only requisite to admit the steam to the opposite side of the turning piston H: this not only stops the crane at once, but also forms an excellent cushion for the piston. Provision is further made at each end of the lifting cylinder A, as well as in the turning round cylinder F, for preventing accident in case the steam should not be shut off at the proper time, by placing a ring of india-rubber Q, Fig. 2, to form a cushion for the piston at each end of the cylinder, so that no damage can be done.

The turning round cylinder F is cased and constantly surrounded with the exhaust steam, as shown in Figs. 2 and 5; this keeps it hot and prevents condensation. The crane post A may be covered with felt and wood to keep it warm: but the crane at the writer's works is not so covered, and although in the open air no inconvenience whatever is experienced from condensation. It might be supposed that in working the crane the steam would condense so rapidly in the crane post that no weight could be held suspended steadily for any length of time; but in practice no perceptible change is observed in the position of the weight

if left suspended for 20 minutes without any steam being admitted into the crane post: there is indeed no perceptible condensation of steam, and no more power is required to lift 2 tons then a pressure of 2 tons upon the area of the piston, with the usual allowance for friction. The crane is blown through at starting in order to clear it of any water that may have condensed in it, and is thereby heated so that it is not found requisite to blow through a second time as long as it continues at work. The blowing through is effected by means of the small mitre valve R placed in the piston B, Fig. 7, Plate 35, kept closed by a spiral spring; but when the piston comes to the bottom of the crane post the valve is opened and allows the steam to pass through the hollow step S of the crane, Fig. 2, blowing out any water through the pipe T; the crane post is thus warmed down to the very bottom. The underside of the lifting piston must communicate with the atmosphere, in order to enable it to work satisfactorily, otherwise in lowering the weight a vacuum would be formed below the piston which would retard the lowering and render it impossible to overhaul the piston and rope when the weight was removed; and as a direct communication between the cylinder and the atmosphere would cause the cylinder to be filled with cold air after every lift, entailing a great loss of heat, to obviate this the blow-through pipe T is connected to the casing of the turning cylinder F, so as to allow the exhaust steam from the casing to follow up the piston B in lowering the weight. The turning round piston H, shown enlarged in Figs. 10 and 11, Plate 35, is made with four brass packing bars pressed up by springs, with a V piece inserted in each of the four corners and kept up by a spring; these corner pieces are made of white metal, and being softer than brass the point will wear as fast as the sides of the packing bars and thereby keep the corners always tight. This piston is made quite independent of the rest of the crane, the packing bars being fitted and ground into their place, springs put in and the cover bolted down before the piston is put in its place; the bolt heads are sunk in the cover, and the fitting strips U carefully planed and well fitted into the radial forked arm H, Fig. 5, which is planed out to embrace the piston. This arm is made of malleable iron and securely bolted to the crane post A; it is made ½ inch shorter at each end than the cylinder F, so

as to allow the crane post to work up or down without jamming the piston in the cylinder. To examine or repair this piston it is only requisite to unscrew and lower the cylinder cover, and the piston can be drawn down from its place and removed entirely. The well in which the crane post A works is kept quite dry by a cast iron lining extending entire to the level of high water, Fig. 1, where a recess is cut out on one side to allow of going down into the well to examine and grease the crane step S at the bottom.

A crane of this construction with a lift of 22 feet and a radius of 20 feet will lift, swing round, discharge, and swing back to reload, 3 times per minute, or will discharge 3 tubs of coal of 2 tons each in one minute, or a greater quantity if the tubs can be filled fast enough. In addition to the expedition of these cranes, the smoothness of their motion and the absence of any jerking, such as takes place with chains and the ordinary gearing, are of great importance, preventing any undue strain upon the foundation or the sudden breakage of chains or other parts of the crane. Smoothness of motion is obviously of great advantage when cranes are used on board ship, for it is well known that the unsteady motion of the present cranes is very injurious to the decks: this is so much the case that it is impossible to keep the decks water-tight for any considerable time; and when covered with lead or sheet iron to prevent the water getting through, the decks and beams are eventually so much injured by the constant jerking and vibration caused by the ordinary steam cranes, that repairs are required more frequently and at more expense than would otherwise be the case.

Another arrangement of this steam crane is shown in the diagram Fig. 12, Plate 35, intended for situations where there is not sufficient depth for the crane post, or where from other causes the post cannot be carried down. In this arrangement the lifting cylinder A, shown black in the diagrams, is laid horizontally below the surface of the ground and the rope is guided to the post by a pulley; the cylinder may be close to the surface, and the rope then pass over a pulley at the stuffing-box and down at an easy angle to the pulley below the crane post. The writer is now making such a crane for the River Tyne Commissioners, for discharging ballast from their ballast barges

into wagons alongside. It is intended to discharge 2 tons of ballast at each lift, and empty it into the wagons, and to deliver at least 1200 tons per day of 10 working hours; the lift is 32½ feet and the radius 25 feet. This arrangement is also suitable for warehouses, the rope leading to the different floors; or the cylinder may stand upright in the warehouse and have a handle on each floor for working it. Figs. 13 and 14 represent modifications of the crane, proposed for application on board ships. In Fig. 14 the jib A is made of malleable iron and forms the lifting cylinder; this arrangement is intended to be used on board vessels where it is not desirable that the steam cylinder should go below the deck. There are also several other situations where this mode of working by the application of a direct-acting steam cylinder with wire-rope piston-rod might be adopted with advantage, such as for opening and closing dock gates and bridges &c.

In making a comparison between the cost of working these cranes by steam or by water, and taking the water at a pressure of 60 lbs. per square inch, the pressure at the writer's works, and steam at 50 lbs. per inch, the writer has found that the cost of steam is but 4½ pence per hour, making allowance for waste; whilst water would be 8 shillings per hour: taking the water at 7*d.* per 1000 gallons, and coals at 14*s.* per chaldron or 5*s.* 3*d.* per ton, the present cost at Newcastle.

Now to make a comparison of the relative amount of work that the new plan of steam crane is capable of doing, and taking the 2 ton crane already referred to for the River Tyne Commissioners, 3 lifts per minute is about the maximum, and 1½ lifts per minute could be maintained; but taking for comparison only 1 lift per minute, this will give 120 tons per hour lifted 32 feet and swung round and discharged, or 1200 tons per day of 10 hours; and the cost of such a machine with boiler and steam pump to feed the boiler would be £460 set to work complete. Comparing this with the actual work of the present steam machine used by the commissioners for discharging ballast, it appears the maximum work is 1 ton lifted 31 feet and swung round and discharged in 2 minutes, and the average not more than 1 lift of 1 ton in 5 minutes; but taking the maximum of the old machine it

would deliver 300 tons per day, whilst the cost was about £400. Adding interest upon the original cost of both machines, wages for men attending to them, and coals &c., the new crane will discharge 1200 tons per day at a cost of about 34*s*. per 1000 tons, and the present machine will discharge 300 tons per day at a cost of 50*s*. per 1000 tons. Thus the new crane, the original cost of which is about the same as that of the old machine, will discharge four times the quantity of material at 30 per cent. less cost per ton.

Comparing the new crane with the ordinary steam crane, it appears that the 2 ton steam cranes of the Hamburgh Steam Navigation Company at Newcastle discharge 20 lifts of 1 ton each per hour, and that the maximum of their work is 25 lifts per hour or discharging 25 tons per hour. The cost of one of these cranes with boiler complete is about £350, and it would discharge 200 tons per day of 10 hours. One of the new direct-acting steam cranes to discharge 1 ton per lift, with boiler, would be less in first cost, and would discharge at least 600 tons per day or three times the quantity.

This crane is simple, easy to work and keep in repair and working order; any intelligent labourer can be instructed to manage it in three or four days; one of the labourers in the writer's works has worked and kept in order the crane at his works since it was started: in fact there is nothing requiring attention, but oiling and packing. In working the crane the man does not require to move a step; he has only to take a handle in each hand, lift and lower with one, swing round right and left with the other; and so little exertion is required that a man could constantly work it for 10 hours per day without intermission.

Mr. Morrison showed a specimen of the wire rope taken off the crane after six months' work. He observed that the packing of the stuffing-box was one of the greatest difficulties anticipated at first; but when the rope was new only a slight blow of steam took place at the stuffing-box when the crane was lowering, and it was quite tight when the full pressure of steam was on in lifting: but after a few weeks' work the slight grooves between the wires of the rope got partly filled up, and the stuffing-box became practically steam-tight both in lowering and raising. There was no trouble with the packing, which was simply alternate layers of gasken and sheet india-rubber, pressed down by a spiral spring giving a constant pressure upon the gland; and only a slight blow of steam was visible after one month's work of the same packing. The turning round piston with square brass packing proved completely satisfactory, and had worked six months without requiring any attention; india-rubber packing was tried at first for the purpose, but was found to fail from abrasion, and lasted only a short time.

The other difficulty anticipated at first was loss from condensation of the steam; but this proved to be remarkably small, as shown by the length of time that a weight was held suspended by the pressure of the steam on the piston in the crane without any further supply of steam from the boiler. He had recently tried the crane standing for half an hour with a load of 45 cwts. suspended from it, and found there was a difference of only 4 inches in the level of the weight during the whole time, although the boiler had remained entirely cut off. The working of the crane was very convenient for management, the lifting, lowering, stopping, or turning round being effected with the greatest ease by the two handles.

Mr. A. Leslie had seen the crane and watched its working for some time, and it was certainly very satisfactory in its action; all the movements were under complete control and managed with great ease and rapidity. He was particularly struck with the packing for the flexible piston rod, which he had not expected could be kept tight; but it worked really steam-tight. He thought the crane was an important improvement, and would prove highly advantageous for many purposes, such as for the decks of steam ships and many other

situations where steam was available and other power could not be conveniently applied; and the great simplicity of the whole and the small number of parts in it were a great recommendation for such cases.

Mr. J. Anderson thought that the comparison given in the paper between the cost of steam and of water power for working a crane could not be correct, as the cost of water power appeared in it so much greater than that of steam; he did not see how that could be the case, for the steam was generated at a distance from the point where it was used, and its application in that manner would be expected to be unusually expensive and extravagant from the extent of cooling surface to which it was exposed; but in the case of water the power would be applied direct without waste. The use of high pressure water for working cranes had proved a very economical and successful means of applying power, and very convenient for working. He asked for some further particulars of the comparison that had been made.

Mr. Morrison replied that the crane stood at a distance of 105 feet from the boiler, and the last 20 feet of the steam pipe was brought under ground, covered over with ashes, the rest being an open pipe passing through the forge. He had not the means of measuring the exact loss of steam from condensation in its passage to the crane, but thought it must be confined within small limits: for the pressure upon the crane piston in lifting a load of 45 cwts. was within 7 lbs. per inch of that in the boiler, which was 48 lbs.; and the loss of steam by condensation in the crane post was shown to be exceedingly small, from the length of time that a load was kept suspended by the same steam. The water power could be readily tried by letting it direct into the steam pipe, and it was taken at the regular pressure in the main of 60 lbs. per inch, nearly corresponding with the steam pressure, and at the actual cost of 7*d*. per 1000 gallons. In the comparison of steam and water power for this purpose, there was another point to be considered in favour of steam: that in using water it was necessary to fill the cylinder all the same, and consequently expend the same power whether a light or heavy weight were being lifted; but with steam the cylinder was filled each time with only the exact quantity of steam required to fill it by expanding to the required pressure for lifting the load.

Mr. E. A. Cowper remarked that for a correct comparison with the cost of water power the comparison should be made with a pressure such as was practically employed for the purpose: water at a pressure of only 60 lbs. per inch was quite out of the question, being a very wasteful mode of applying the power; but a pressure of 600 or 700 lbs. per inch should be taken, such as was used in hydraulic machinery, when a proportionately smaller quantity of water would be consumed. Also as to the amount of waste of steam from condensation in the steam pipe, no deduction could be drawn from the circumstance of the boiler pressure being maintained at the crane during working, since the pressure would be kept up in the pipe so long as it was in open communication with the boiler, however great a waste of steam might be going on by condensation in the pipe; unless the area of passage were actually too small to convey the required quantity of steam from the boiler for keeping up the pressure, when the steam would of course be wire-drawn and the pressure lowered in the same way as if the crane cylinder were taking steam faster than the area of steam pipe could supply it. He thought that from the extent of surface exposed in this case there must be a considerable loss of steam by condensation.

This crane would probably be found most advantageous for continuous and rapid work, such as discharging ballast at a fixed station, and in situations where a single crane only was required; and where the greater cost of apparatus requisite for a hydraulic crane would make it unsuitable. Otherwise, as to economy of power, the quantity of water used was in proportion to the lift; but this was not the case with steam, which also suffered the loss of a considerable proportion of its power, particularly where the crane was not in continuous work, the cylinder being then allowed to cool after each time of using: whereas water power was always equally ready for action without loss, however irregular and intermittent the work might be.

Mr. Morrison observed that the expense of construction would be greatly increased in the case of water power of high pressure, by the accumulator required for obtaining the pressure. Where several cranes were required in a row along a quay or elsewhere, they could be worked with one boiler, making the whole apparatus very simple

and economical in construction; and steam was frequently conveyed long distances in covered pipes for working engines.

Mr. S. Bastow said there were several steam cranes working at the West Hartlepool Docks, that he had constructed for discharging ballast, each of which discharged about 60 tons per hour, lifting 1 ton at a time; they were on the ordinary construction, and did not swing round, but tipped over the bucket when it was lifted and the jib was raised; and this arrangement was found convenient and expeditious for the purpose. It might be a question whether a larger weight lifted at a time would not be more economical, but the amount of the weight was limited by its having to be handled in tipping; and if the weight was required to be swung round, there would certainly be an advantage in the crane now described, in saving time by swinging it round partly at the same time as hoisting. The crane was conveniently arranged for working, and he much admired the direct action of the steam in raising the load, which greatly simplified the construction and was a very ingenious plan.

Mr. Morrison observed that the working of several different plans of cranes for discharging ballast had been examined by the River Tyne Commissioners, and they had decided upon this crane for the purpose, on account of its convenience and rapidity of working and simplicity of construction.

Mr. E. A. Cowper enquired whether the turning round piston was found quite large enough as shown for swinging the crane round quickly, as it had so short a leverage to act at.

Mr. Morrison replied that the piston first used was only 10 inches square and was not found large enough, but the present one 10 by 15 inches swung the crane round readily with 48 lbs. steam; this piston had little friction and worked very satisfactorily.

The Chairman moved a vote of thanks to Mr. Morrison for his paper, which was passed.

The following Paper was then read:—

DESCRIPTION OF A NEW STEAM PRESSURE GAUGE.

By Mr. ALEXANDER ALLAN, of Perth.

There are a variety of gauges in use for indicating pressure, acting generally on the principle of the deflection of metallic springs by the pressure; the springs being in various forms, flat discs, spiral, tubular, &c., and marking the pressure by an index upon a dial, propelled by the deflection of the spring by means of a multiplying motion. The new Pressure Gauge, forming the subject of the present paper, was designed by the writer with the view of obtaining as far as practicable a gauge which with great accuracy should possess extreme simplicity, indicating the pressure without the intervention of any mechanism, and be capable of readjustment at any moment without interfering with its use. The principle of this gauge consists in indicating pressure, either above or below that of the atmosphere, by the more or less compressed or expanded condition of a measured quantity of air contained within the gauge; this is acted upon by the pressure through water or other fluid contained within a bent pipe, which is attached at one end to the gauge and at the other end to the boiler or vessel containing the pressure to be indicated; the surface line of the water, as seen in a glass tube attached to the body of the gauge, indicates the extent of pressure on a graduated scale.

Plates 36 and 37 show different forms of this pressure gauge. Figs. 1 to 4, Plate 36, show a gauge arranged to indicate pressure up to 160 lbs. per square inch above the atmosphere. The body of the gauge is formed of a pillar of brass A, which may be of any convenient external shape; but the interior chamber must be of the tapered form shown in the drawing: this chamber is cored out and closed at the top by a plug B, and at the bottom by the three-way cock C, Figs. 1 and 5, which is supplied with a union joint for attaching to the bent pipe

from the boiler. The brass pillar A has two projections communicating with the interior chamber, bored out to receive the glass tube D, which is made tight at each end by being pressed against elastic washers by means of a screwed nut E at the bottom. The gauge having been proved and marked with a correctly graduated scale is fitted to the boiler in the manner shown in Fig. 11, Plate 37. The bent pipe F, bent in a U form, is filled with clean water and attached to a stopcock G on the boiler and to the gauge A, the three-way cock C being open to allow the water to rise in the gauge; the stopcock G is then opened, and the pressure acting on the water contained in the bent pipe F forces it up into the chamber of the gauge to a height corresponding to the pressure; and the glass tube being open to the chamber at top and bottom, the water rises in it to the same height as in the chamber, thus indicating the pressure upon the graduated scale.

In consequence of some air being contained in the bent pipe F, the first indication may be incorrect, but is readily corrected by shutting the three-way cock C against the pressure and opening it to the atmosphere; all the water in the body of the gauge then runs out and the gauge is left filled with air above the orifice of the cock C, which being then shut to the atmosphere and opened to the pressure, the gauge will now indicate exactly the amount of pressure in the boiler. In order to allow of expeditiously emptying the gauge at any time of any surplus water that may have got into it, owing to leakage or condensation of the air, a small thumb screw H, Figs. 1 and 6, with a passage through it is provided at the bottom of the glass tube D; this is slacked back a few turns, as in Fig. 6, while the three-way cock C is open to the gauge and the atmosphere, enabling the water to flow out freely through the cock, so that the gauge is accurately refilled with air: the screw H is made tight at the collar by a small leather washer. The gauge thus possesses the very important quality of admitting of instantaneous readjustment, as the quantity of air in it can in this way be remeasured every time it is looked at; and with this facility of correction the errors likely to arise with gauges not so easily tested are got rid of.

This gauge is very sensitive. It is found in practice that if the pressure be rising the surface of the water assumes a slightly convex

form in the glass tube, and if falling is slightly concave; the extreme amount of concavity and convexity is not more than 0·1 inch, and yet indicates the slightest change in the pressure. The gauge being composed of anticorrosive materials is not subject to deterioration: the glass tubes are all made to gauges for length and internal diameter, so that should one be broken by accident a change of glass will not affect the indications or require an alteration of scale; and the tubes will stand a pressure of 500 lbs. per square inch. The inside chamber of the gauge is made of the tapered form shown in Fig. 7, Plate 37, for the purpose of getting the divisions on the graduated scale nearly equal throughout; for with a parallel chamber the divisions are large at first and gradually diminish under higher pressures till they become too minute for observation. The screwed plug B, Fig. 1, closing the chamber at the top and the end of the cock C at the bottom are useful for rectifying any little defect in the casting, as the volume of air under pressure in the gauge may be increased or diminished at top or bottom as may be found necessary in proving the gauges.

Figs. 8 and 9, Plate 37, show a modification of the gauge for a pressure up to 50 lbs. per square inch; the only difference from the previous gauge being the insertion of the tube I above the cock C, whereby the quantity of air subjected to pressure is less, being determined by the height of the top of the tube I, which may be varied to suit any pressure between 50 lbs. and 150 lbs.; this arrangement also tends to simplify the manufacture of the gauge. Fig. 10 shows the simplest modification of the gauge, having a tapered glass tube A, sealed at the top and held at the bottom in a metallic base, being made air-tight by means of elastic washers: it has been found however that there is great practical difficulty in making the glass tubes of the correct form so as to get a uniformly graduated scale; and therefore a metallic chamber as previously described answers better in practice.

In Fig. 11, Plate 37, the steam pressure gauge A is shown attached to the weatherboard of a locomotive boiler, with the bent pipe F and stopcock G communicating with the steam space of the boiler; this arrangement is preferred in order to get pure water by condensation, and for the same purpose the pipe F should be as large as convenient. If the gauge be frequently corrected, the water in the pipe must not

be allowed to become heated, otherwise it will interfere with the correctness of the indications; this will not however occur unless the quantity of air in the gauge be remeasured more frequently than is necessary.

Fig. 12 shows the proving apparatus used in making the gauges. It consists of a brass pump J having a ram exactly 1 square inch area, which is fitted with a piece of leather carefully turned to move freely in the pump; the weight is applied directly to the ram by means of flat metal weights K suspended by a rod, and the lever L is used for relieving the weight. There is no sensible friction in the apparatus, as it is very carefully made and fitted up; and it is now so correct that up to a pressure of 200 lbs. per square inch it is accurate, and checked by a Bourdon gauge is found to agree to every 5 lbs. added. The drawing shows the improved gauge A attached at one side of the proving apparatus and a Bourdon gauge M at the other.

About 13 high pressure gauges are now in use on steam boilers, and are working well and giving every satisfaction.

Mr. Allan showed specimens of the pressure gauges, and a working model of the testing apparatus used for adjusting them, showing the indication of a gauge at different pressures; and the action of readjusting the gauge by letting out and renewing the supply of compressed air in it. He observed that his object had been to obtain a gauge giving a direct indication of the pressure, without the intervention of any machinery incurring the liability of getting out of order, and one that could at any time be readily tested and readjusted without requiring removal from its place or any special arrangement. The gauges for different ranges of pressure were alike, excepting in the difference of size of the lower parallel portion of the air chamber; and the only difference between a 100 lbs. and a 50 lbs. gauge was in

having the lower part of the chamber shorter for the lower pressure, so as to contain a smaller quantity of air as the unit of volume for measurement; the curved shape of the interior of the gauge then allowed the divisions to be nearly uniform throughout the scale in both cases.

Mr. R. B. Longridge thought it was an ingenious plan for removing the objection attaching to previous compressed air gauges, that the indication was liable to become permanently wrong by some steam working its way up through the mercury to the surface; the arrangement for readjustment in this gauge was certainly very ingenious and satisfactory: the uniform graduation of scale was also important. He enquired what was the cost compared with the other pressure gauges in general use.

Mr. Allan replied that only a small number of the gauges had been made yet, and the question of cost had not yet been considered; but it was not likely to be more than that of other pressure gauges, and would probably be less. The object at present had been to get a really accurate pressure gauge, that could be fully relied upon and admitted of instant checking and readjustment.

Mr. E. A. Cowper thought the principle of the gauge was a very good one, and it was likely to prove very serviceable. A metallic spring was subject to error from straining or partial loss of elasticity, and metallic gauges were all liable to get somewhat out of order in consequence; and there was no means of ascertaining and correcting the error except by incurring the trouble and inconvenience of removing the gauge and specially testing it. But an air spring could not get out of order, and the very ingenious contrivance for renewing the air whilst at work effectually removed the objection to previous compressed air gauges; for air under pressure was absorbed to a small extent by water, and therefore required renewal independent of any loss from leakage, as was shown in the air vessels of pumping engines where a constant supply of air had to be pumped in to prevent them from becoming gradually emptied of air. The tapered form of the air chamber giving nearly uniform graduation for the scale of pressure was an important advantage over the former compressed air gauges, where the higher divisions of pressure were so small as to be of little use.

From the simplicity of construction of the gauge he thought it must prove economical in make as well as maintenance; and the continued accuracy ensured by the ready means of testing and readjusting it was an important point in giving confidence in its use.

Mr. J. Tomlinson had tried the gauge, and had had one of them working at 120 lbs. per inch upon a locomotive on the Taff Vale Railway for about a month; he found it work very satisfactorily, and it appeared the best gauge of any he had yet tried; the indications were very correct and kept in correspondence with the safety valve. Metallic pressure gauges he found generally indicated to a certain extent too high after being some time at work; they were also liable to be spoiled by over-straining or breaking, if the high pressure steam were let on with a sudden blow: but the new compressed air gauge was quite safe from injury. The only precaution that was observed in using it was to take care to leave the syphon pipe always charged with water at night, so as to have the gauge ready for action the next day without having to wait for a supply of steam to fill the pipe again with condensed water; but even this process caused very little delay or inconvenience. He had fixed the gauge at first with a syphon pipe only 2 feet long, but found a longer pipe was preferable in order to keep the water cold and maintain a good supply; the gauge was now fixed with 6 feet length of pipe, which proved quite satisfactory, and remained constantly cold beyond the first 1 or 2 feet of length: and he found no difficulty or inconvenience in the working of the gauge.

Mr. Allan said he had tried the gauge continuing for a fortnight at work on a locomotive engine with the same water and air in it, and found it remained very nearly correct in indication; but as the means of changing was so simple and ready, the custom was to shut the water in the syphon pipe at night, and the engineman emptied and recharged the gauge every day, when trying the other gauge cocks on coming to the engine in the morning. A little difficulty was experienced with this at first from the cock of the gauge being turned too often, and the supply of water wasted; but the men soon got into the way of working the gauge regularly, and keeping it right without difficulty.

Mr. R. Brown had one of the gauges working for some months attached to the dome of one of the boilers at the Patent Shaft Works, Wednesbury, and was much pleased with its action; it had kept in complete order without any trouble, and was so sensitive as to show each stroke of the engine by the fluctuation in pressure. Looking at its simplicity of construction and freedom from liability to error or derangement, he thought it the best plan of pressure gauge he was acquainted with.

Mr. B. Fothergill thought it a very sensible construction of gauge, and one likely to prove very satisfactory in working. He moved a vote of thanks to Mr. Allan for his paper, which was passed.

The following Paper was then read :—

DESCRIPTION OF HASTE'S IMPROVED SAFETY VALVE FOR STEAM BOILERS.

By Mr. WILLIAM NAYLOR, of London.

In the explosions of steam boilers, which are still of frequent occurrence, the cause of the explosion too often remains a mystery, and is not satisfactorily ascertained so as to afford a guide towards guarding against the recurrence of such accidents. The author has a strong impression that in several cases of boiler explosions the cause has been simply over-pressure beyond the calculated or known pressure in the boiler; and that the over-pressure was caused by the safety valve in use not carrying away the steam as fast as it was generated. In three cases that came under his particular observation, the firing was going on as if the engines were in full work; whereas neither were the engines at work, nor was any feed water being pumped into the boiler for some 10 or 15 minutes before the explosions took place: consequently the boilers were generating as much steam as would have supplied the engines at work; and in addition the amount of fuel required for heating the feed water from the temperature at which it entered was spent also in generating steam, so that more steam had to pass away through the safety valve than was necessary to work the engines at their full power.

A safety valve loaded to a certain pressure per square inch, so that whenever that pressure is attained in the boiler the least addition to it will cause the steam to begin to escape, is not by any means a guarantee that the steam will be carried away as fast as it is generated, and no surplus pressure allowed to accumulate in the boiler above that at which the valve is loaded to blow off; and it appears from experience that ordinary safety valves do not effect this object, as further shown by experiments afterwards described. At the time when 50 lbs. per square inch was the working pressure in locomotive engines, say 25 years ago,

the practice was to have one valve loaded by a lever and spring balance to 50 lbs. per square inch, and a second valve similarly loaded up to 60 lbs. per square inch. The author has frequently noticed that when the one at 50 lbs. was blowing off strongly the one at 60 lbs. would begin to blow off, and often both valves would blow off very strongly; proving that there must be a surplus pressure of at least 10 lbs. per square inch above that at which one valve was intended to carry the steam away as fast as it was generated. Such valves loaded by levers and spring balances are very generally used on boilers supplying moderately high pressure steam to stationary engines, and also on locomotive engines; but they are defective under the most favourable circumstances, if required to pass any great amount of steam; and they are open to the objection that they may be overloaded by weights being added on the lever. In this respect there are a few valuable exceptions, but only a very few, in use at the present time.

The want of a sufficient amount of water in the boiler is also no doubt the chief cause of many explosions of steam engine boilers, more especially those attached to stationary engines. For by the water getting below the top of any portion of the heating surface which is acted upon by the fire, that portion soon becomes overheated and reduced in strength, until it is unable to bear the pressure of the steam upon it; under these circumstances something must give way, and the result must be an explosion.

It is therefore desirable that an arrangement of safety valve should be adopted which will accomplish the three following objects: to carry off the steam as fast as it is generated above the pressure the boiler is intended to work at; to be entirely out of the reach or control of any one to tamper with or overload it; and to be so arranged that, in the event of the water getting low in the boiler, the valve shall blow off steam and avoid the possibility of any explosion or injury beyond the burning of the plates if more water be not supplied.

The plan of safety valve forming the subject of the present paper, which is the invention of Mr. J. Haste of Leeds, has proved highly successful in accomplishing these objects. The arrangement is represented in Fig. 1, Plate 38, showing a section of the valve and

its connexion with the boiler; Fig. 2 shows a section of the valve enlarged.

The valve A, by which the steam escapes into the atmosphere when the limit of pressure is exceeded, is made with two seats, the upper one being 3 inches diameter and the lower 3¼ inches diameter, the difference being 1·23 square inch area. The steam presses on both ends of the valve, passing up through the middle of it, so that when the valve is open the steam escapes at both ends into the casing surrounding the valve and thence into the atmosphere. This valve is not moved off its seats by the steam acting upon the difference of area of the two ends, but is forced open by steam acting upon the piston B, the rod of which presses upon the valve A. The small safety valve C, by which the limit of pressure of the steam is fixed, is loaded by a dead weight D enclosed in a chamber and guided at the top by a small piston E working in a cylinder of the same area as the valve C below. Whenever the pressure of steam in the boiler exceeds that to which the small valve C is loaded, it will be raised from its seat; and the steam escaping will accumulate in pressure upon the top of the piston B. The area of this piston is 7 square inches, or nearly 6 times the difference of area of the valve seats A. Taking the pressure of steam in the boiler at 35 lbs. per square inch, there is a force of 42 lbs. tending to keep the escape valve A closed, equivalent to a pressure of 6 lbs. per square inch on the under side of the piston B; so that when the pressure above the piston has reached 6 lbs. per square inch, any increase of pressure must open the escape valve A: and if there be a pressure of 35 lbs. per square inch upon the piston B, this gives a force of 245 lbs. tending to open the escape valve against a resistance of 42 lbs., leaving an effective force of more than 200 lbs. to open the escape valve A. Upon the area of opening afforded by the valve will depend the efficiency of its action in preventing a surplus pressure of steam from accumulating in the boiler.

One of these safety valves, of the construction shown in Plate 38, is attached to a boiler at the works of Messrs. Bray and Waddington of Leeds. The boiler is 24 feet 3 inches long and 6 feet 6 inches diameter, with two flues of 2 feet 6 inches diameter, and firebars 6 feet long in the flues, giving an area of firegrate of 30 square feet: it

supplies steam to three non-condensing engines of 34 total horse power, working at 35 lbs. per square inch pressure. In order to ascertain by experiment the action of the valve, a pressure gauge was attached to the top of the chamber D in addition to one placed on the boiler: the small valve C was loaded to 35 lbs. per square inch. After many trials with the whole of the steam that the boiler could generate passing through the escape valve A, the pressure did not exceed 37 lbs. per square inch in the boiler or a surplus pressure of 2 lbs. per inch. The valve A was then purposely prevented from blowing off until there was a surplus pressure of 3 lbs. per square inch upon the piston B as well as in the boiler, as shown by the two pressure gauges; the valve A was then forced full open by the pressure of steam, and it was found that the pressure in the boiler was reduced to 35 lbs. per square inch in a few minutes.

In order to ascertain the real value of this safety valve as compared with the ordinary valve, the following experiments have been tried by the writer, in which every care was taken to prevent error in the result: the fires were clean and free from clinker, the fuel good coal and well ignited; none of the engines were at work, nor was there any outlet for steam to escape except those intentionally allowed; nor was any feed water pumped into the boiler during the time of experiment.

The first object in the trials was to ascertain how fast the pressure of steam could be raised to the point of blowing off; say from 5 lbs. up to 35 lbs. per square inch. This time was found to be 13 minutes, making 2·3 lbs. rise of pressure per minute.

The next object was to see how the pressure would be affected by an opening of 1 square inch area being allowed for the steam to escape through; and when the pressure had been raised to 35 lbs. per square inch, a slide valve was opened turning the steam into a 4 inch branch pipe, upon which was bolted a plate with a hole of 1 square inch area, through which the steam escaped freely into the atmosphere. It was then found that the pressure in the boiler oscillated between 35 lbs. and 43 lbs. per square inch; and at the end of 45 minutes the maximum of 43 lbs. pressure was attained. The slide valve was then

shut and the steam turned on so as to pass out by the new safety valve, shown in Fig. 1, Plate 38; the pressure gauge on the boiler and that on the chamber D both showed 43 lbs. per inch, and the escape valve A was instantly forced full open and down upon the studs below it. The pressure in the boiler was then reduced by the valve from 43 lbs. to 38 lbs. in the first 5 minutes, and finally to the ordinary working pressure of 35 lbs. in 15 minutes. The firing for the whole hour had been much forced, and was much above that necessary to drive the engines in their ordinary work. On observing the water level it was found that in the hour 57·5 cubic feet of water had been evaporated into steam, which would be sufficient to have supplied a 60 horse power engine. Hence with this generation of steam a hole of 1 square inch area was sufficient to keep the pressure down to 43 lbs. per square inch during 45 minutes; while with the new safety valve the pressure was reduced to 35 lbs. in 15 minutes.

An experiment was then tried to ascertain how far an ordinary safety valve of 3¾ inches diameter would keep the pressure from accumulating in the boiler above that at which it was set to blow off. The valve was loaded by a lever and spring balance, as shown in Fig. 3, Plate 38; and 1 lb. on the balance was equal to 1 lb. per square inch on the valve. When the pressure gauge upon the boiler showed 43 lbs. per square inch and the spring balance was set at 43 lbs., there was a very slight blowing off at the valve, showing that the pressure gauge and spring balance agreed. The spring balance was then slacked back to 30 lbs., allowing the steam to blow off freely; in 5 minutes the pressure gauge on the boiler showed 46 lbs., in another 5 minutes 46½ lbs., and in 5 minutes more 46 lbs. Thus for 15 minutes, with a valve loaded to only 30 lbs. per square inch above the atmosphere, the actual pressure in the boiler was 46 lbs., being a surplus of 16 lbs. above the pressure that the valve was adjusted to blow off at, or 35 per cent. of surplus pressure. In the previous experiment it has been seen that an opening of 1 square inch area carried off the steam as fast as it was generated, without allowing the pressure to exceed 43 lbs. per square inch. But in the present case, with a valve of 3¾ inches diameter or 11 square inches area, in order to give an opening of 1 square inch area round the circumference, ·085 inch width of opening would

be required, or ·122 inch vertical lift of the valve, the circumference being 11·78 inches, and the face of the valve being inclined at an angle of 45°. This lift of the valve would extend the spring balance 1·34 inch, the leverage being 3¼ and 35¾ inches; and as the scale of the spring balance gave 12 lbs. for each inch of extension, an excess of pressure of 16 lbs. per square inch would be caused by this lifting of the valve in blowing off, which would give an area of opening of only 1 square inch for the steam to escape. This result agrees with the observed surplus pressure of 16 lbs. per square inch. In the ordinary safety valves there is also frequently a cause of over-pressure, in consequence of the valve being enclosed in a chamber, from which the steam escapes through a pipe into the atmosphere: if the steam is roaring through this pipe there must be some pressure of steam in the chamber to occasion that roar, thus causing an increased pressure on the valve above the limit to which it is intended to be loaded.

The other source of explosion,—the want of water in the boiler,—is provided against in this safety valve by the float F, which on falling below its proper level opens the escape valve A, and lets the steam escape from the boiler to the atmosphere regardless of its pressure. The author has found by repeated trial and the results of regular working that, whenever the water gets below the working level in the boiler, the float descending with it opens the escape valve, allowing the full opening for the discharge of the steam, and the valve cannot be closed again by any other means than the proper supply of water, raising the float to its original level. In experimenting upon the boiler, when the escape valve was opened by the float to the full extent, the pressure of steam was reduced at the rate of 2 lbs. per square inch per minute. The loud noise of the steam escaping could not fail of itself to call attention; but even if not attended to, the only result would be that the steam would be all let out of the boiler, and the engine stopped, all danger of accident being avoided.

Mr. Naylor showed a sectional model of the valve and apparatus, and observed that the object was to ensure the pressure in the boiler never rising beyond the intended limit, by opening an escape for the steam when that limit was reached equal to the passage of the whole quantity that the boiler was capable of generating, and ensuring this passage being kept open until the pressure fell just below the fixed limit. The ordinary safety valves did not provide for this, and although there were some excellent constructions of valves to prevent overloading, such as Mr. Fenton's and Mr. Ramsbottom's safety valves, there was still no provision for preventing the pressure rising beyond the intended point when the boiler was generating steam rapidly, although the safety valve was in action; and a supplementary valve was required for this purpose, which would give a large area of discharge, by suddenly opening as soon as the limit of pressure was reached, effectually preventing any increase of pressure beyond that point. The same escape valve was also made to act in this apparatus to discharge the steam if the water in the boiler sank below the proper level; and it had this additional security against accident, that the continued escape of steam could be stopped only by the supply of water being again raised to the proper level: thus entirely preventing any risk of explosion, and acting as a strong inducement to the attendant to prevent a fall of the water level from occurring.

Mr. B. Fothergill observed that the principle of opening a supplementary escape valve, and causing it to be kept open so long as the pressure exceeded a fixed limit, was certainly an efficient one for ensuring the pressure being always limited to that point, which could not be effected by safety valves with spring balances; and if such an apparatus were simple and certain in its action, so that it could be fully depended upon, it would prove an important source of safety in steam boilers. He had seen a safety valve on that plan, contrived by Mr. Kay of Bury, that had been before a former meeting of the Institution, which he believed was working successfully.

The Chairman thought in any arrangement of the kind there still remained the objection of risk of the safety valve sticking; and in this plan the whole action depended upon the small safety valve keeping all right, which was liable to the same risk of derangement as

ordinary safety valves, and in a greater degree on account of its small area compared with its length of circumference in contact with the seating. It appeared to him doubtful whether it was a safe course to pursue, to make the safety of the boiler dependent on the action of a single small valve, as was in effect the case in such an arrangement; and he thought it would be more correct to increase the area or number of the safety valves, if they were not found sufficient to keep down the pressure within safe limits. He enquired how long the apparatus shown had been at work.

Mr. NAYLOR replied that it had been working regularly for 1¼ year, and had proved quite successful, and no imperfection had been found in its action. The action of the escape valve was certainly dependent upon the small safety valve, but he thought this was by its construction very free from risk of derangement and might be safely relied upon; and the pressure upon it could not be increased. The large area for discharge of steam given by the sudden opening of the escape valve was he thought a more efficient provision for preventing any increase of pressure than could be practically obtained with ordinary safety valves with spring balances.

Mr. H. MAUDSLAY observed that in marine engine boilers it was usual to put two large safety valves, either of which would be sufficient to prevent any material increase in the boiler pressure, so as to afford a safe provision even in the case of one of the large valves failing to act from any cause. In safety valves he thought it was objectionable to have anything like a piston valve, on account of the liability to deposit collecting upon the rubbing surface and causing the valve to stick; and more particularly in the case of a locked up valve where it was liable to be left unopened for a long time, and a deposit might form, though very slowly, sufficient to impede the proper action of the valve. It was the essential point to be aimed at in any construction of safety valve to ensure certainty of action, as well as freedom from liability to derangement.

The CHAIRMAN moved a vote of thanks to Mr. Naylor for his paper, which was passed.

The Meeting was then adjourned to the next day, and the Members proceeded to visit the Flax Mill of Messrs. Marshall & Co., and several other engineering and manufacturing establishments that were thrown open for their inspection.

In the evening the Members and their friends were invited by the Local Committee to a Conversazione in the Victoria Hall of the Town Hall, where a number of engineering models, drawings, and photographs, philosophical instruments, and an extensive series of objects under microscopes, were exhibited.

The Adjourned Meeting of the Members was held in the Civil Court, Town Hall, Leeds, on Wednesday, 7th September, 1859, at half-past ten o'clock; John Penn, Esq., President, in the Chair.

The following Paper was read:—

ON THE APPLICATION OF SUPERHEATED STEAM IN MARINE ENGINES.

BY THE PRESIDENT.

An opinion in favour of Superheating the Steam supplied to steam engines has long existed, and it has been maintained by many that important advantages might be obtained from this principle; though until recently but little has been effected in its practical application, and much doubt has been felt as to its advantages proving sufficient to lead to its general adoption. The development of the principle has probably been checked by exaggerated ideas being entertained respecting its advantages on the part of its earlier advocates; and also by somewhat incorrect views of the action of superheated steam, leading to attempts to carry the superheating to an excessive degree, thereby involving much extra risk of failure and stoppage of the apparatus, and tending to discourage further pursuit of the object.

Superheated steam seems to have been definitely tried about 27 years ago by Mr. Thomas Howard of Rotherhithe; but in this case the boiler or vaporiser was dry, and only enough water was injected at each stroke of the engine to supply the necessary quantity of steam. It would appear from the experiments made that very considerable economy was effected; but although the apparatus thoroughly established the principle, it was too delicate in its construction, and was for this reason given up. Mr. Howard appeared to be fully alive to all the advantages of the system, and always expressed his opinion that there was a loss of 30 per cent. in an ordinary steam engine, which would be recovered by superheating the steam. Soon afterwards the late Dr. Haycraft of Greenwich took up the subject and advocated it strongly, being convinced that great advantages would be obtained by superheating the steam in engines; and he used to express his confidence that the time would come when the principle would be generally adopted, and that a saving of 30 per cent. in the consumption of fuel would be thereby effected.

The importance of the principle was first impressed upon the writer many years ago by Mr. Howard and afterwards by Dr. Haycraft, with both of whom he was very intimate; and he has become satisfied from the results of experiment and observation that important advantages in economy of fuel may be obtained from the system; the main question to be settled being whether it involves any serious practical objection from complication of apparatus, risk of derangement and failure, or difficulty in lubrication of the engine. The recent trials he has made on a large scale have led him to the conclusions :—

That an advantage can be obtained from the use of superheated steam amounting to an economy of fuel of from 20 to 30 per cent. in marine engines;

That a moderate extent of superheating enables all the important advantages of the plan to be obtained;

And that apparently nothing objectionable is then necessarily involved from extra wear and tear, risk of failure, complication of apparatus, or difficulty in lubrication.

The real source of advantage in employing superheated steam appears to be in preventing the presence of any water in the cylinder of the engine, and ensuring that the cylinder shall never be occupied by anything but pure steam; making it a real steam engine, instead of one working with a mixture of water and steam. In all condensing engines the interior of the cylinder being open to the condenser during half the time of each revolution of the crank is in communication during that time with the low temperature of the condenser, or about 110° when the vacuum is 13½ lbs. per inch below the atmosphere or 27 inches of mercury. There is consequently a rapid radiation of heat from the sides and end of the cylinder, cooling down the whole mass of metal. The steam admitted into the cylinder in the next stroke, at a temperature of 260° if at 20 lbs. per inch above the atmosphere, coming in contact with these cooled surfaces, heats them up again, being robbed thereby of a portion of its heat; and the consequence is the deposit of a quantity of water in the cylinder, from condensation of an amount of steam proportionate to the quantity of heat imparted to the metal of the cylinder. A portion of this water in the cylinder may be evaporated again into steam towards the end of the stroke, by

carrying the expansion of the steam down to a sufficiently low pressure; but even then its effective value as steam in propelling the piston will have been lost during all the previous portion of the stroke. The engine must in fact be looked upon as only in degree better than Newcomen's atmospheric engine, in which the whole of the steam was condensed in the cylinder at each stroke; and the advantages of Watt's great invention of condensation in a separate vessel are not fully realised until this serious defect is removed. Now if as much heat be added to the steam by superheating it before entering the cylinder as will supply the amount of which it is robbed by the cylinder, it will remain perfect dry steam throughout the stroke, and not a drop of water will be deposited. This the writer believes to be the mode in which the superheating of steam acts in producing a saving of steam and consequent economy of fuel, by preventing the extensive waste of steam that ordinarily takes place: and this indicates the extent to which the superheating can be carried with any great advantage. The writer believes that an addition of 100° of heat to the temperature of the steam ensures the accomplishment of the desired object with steam at 20 lbs. per inch above the atmosphere, as used in marine engines; the steam is thus heated from 260° to a temperature of 360°, and is then only about as hot as the ordinary high pressure steam of 120 lbs. per inch used in locomotive engines.

The plan of superheating the steam before entering the cylinder is a simple and eligible mode of attaining the desired object, and appears also to be preferable to a steam jacket. For when the steam is supplied to the jacket from the same boiler as the cylinder, the supply of heat to the metal will be slower than in using superheated steam, owing to the difference of temperature being less; and to carry out the object fully requires the steam in the jacket to be superheated, and the cylinder covers to be also jacketed, since in the short-stroke marine engines where the diameter is nearly double the length of stroke the area of the two covers or ends equals that of the sides. But even then the application of the heat by the steam jacket is outside the cylinder, and the heat is delayed in its action by having to pass through the thick metal; whereas by the introduction of superheated steam into the interior of the cylinder the object is accomplished in

the most direct manner, by heating the surface with which the steam comes in contact, and even a momentary chill of the steam down to the condensing point is entirely prevented. By superheating the steam with the waste heat of the smokebox, not otherwise usefully available, all this effect is obtained without cost; but with the steam jacket the heat used has to be supplied from the boiler. An important practical advantage attending the use of superheated steam is obviously that all objectionable joints for steam jackets are avoided; and the cylinder being felted and lagged the same as the steam jacket, there will be no more loss of heat by radiation from the outside.

The mode of superheating the steam may be varied in many ways: a general principle to be aimed at being to make use of the waste heat for this purpose after leaving the boiler, so as to accomplish the superheating without any cost of fuel; and to place the apparatus where it will not be exposed to injury from too great heat. The superheating apparatus has generally been placed in the smokebox or uptake flue in marine boilers, and has consisted of faggots of tubes or coils of pipe for the purpose of obtaining the required extent of heating surface within a limited space.

The accompanying drawings, Figs. 1 and 2, Plates 39 and 40, show the arrangement used by the writer and employed in a recent extensive trial of the plan in the Valetta steamer of the Peninsular and Oriental Company, of 260 nominal horse power, running between Malta and Alexandria. In the smokebox AA of each boiler are placed two horizontal faggots of tubes BB, forming the superheating apparatus, each consisting of 44 wrought iron tubes 2 inches diameter inside and 6 feet 3 inches long, placed in vertical rows with clear spaces between them horizontally for allowing ready access in cleaning the boiler; these spaces are left opposite each row of tubes in a tubular boiler, but in the present case the boiler is constructed with Mr. Lamb's vertical flues in place of tubes. The superheating tubes BB are fixed into the three flat chambers CCC, which are made of wrought iron welded up at the corners and closed each with a single flange joint. The steam is supplied from the boiler to the centre chamber through the stop valve and pipe D, and is taken off from the end chambers

by the stop valves EE communicating with the steam pipes FF leading to the engines. The steam is thus made to pass through the superheating pipes on its way to the cylinders, and becomes superheated by taking up a portion of the waste heat escaping from the boiler flues before reaching the uptake flue G leading to the chimney. The steam pipes FF have also the ordinary direct communication with the boiler through the second stop valves HH, so that the whole superheating apparatus or either half of it can readily be shut off and disconnected at any time if desired.

The vessel has made two trips from Malta to Alexandria and back, a total distance of 3276 miles, with the superheating apparatus; and then two of the same trips without the apparatus, but with no other alteration. The result was a saving of 20 per cent. in the consumption of fuel, although the men were not experienced in the management of the apparatus; and there appears every reason to believe that when the apparatus has been a little longer time in use the saving will be still greater. The main object kept in view in the detail of construction of the apparatus was to ensure a simple and durable plan that would not require any repairs for a long time; and for this purpose the superheating tubes were made a thorough mechanical fit, and free from strain of expansion tending to make them leaky. The wrought iron tubes are $\frac{3}{16}$ inch thick and have thick ends welded on to them, as shown half full size in Fig. 3, Plate 40; these are turned down to a square shoulder, and all correctly to the same gauge for length, and fitted tight into the holes of the tube plate, which is also planed on the face and accurately bored; the tubes are then pressed into their places all at once by the plates being drawn together with screws, and are made steam-tight by the fit alone; the ends of the tubes are then expanded, as shown complete in Fig. 4. The total area of superheating surface including the wrought iron boxes is 374 square feet in each of the two boilers, giving a proportion of $2\frac{3}{4}$ square feet of superheating surface per nominal horse power, the engines being of 260 nominal horse power and the boilers having a heating surface of 19 square feet per nominal horse power: this proportion appears from the writer's trials to be sufficient for superheating the steam to the extent that is desirable. The apparatus has

not leaked or failed in any way during the time it has been at work, and appears likely to prove very durable.

The heat employed for superheating the steam is taken entirely from the waste heat after leaving the boiler, which would otherwise have escaped by the chimney; and this abstraction of heat from the smokebox together with the screen of superheating tubes shielding the smokebox doors has produced a marked effect in keeping the stoke hole uniformly much cooler when the superheating apparatus was applied than without it. The temperature of the steam is constantly indicated by a thermometer, which is fixed in a small cup projecting into the interior of the copper steam pipe and containing a little mercury at the bottom in which the bulb of the thermometer is immersed. The fluctuations of this thermometer indicate very delicately the variations in temperature of the steam; and the mercury in the thermometer is affected considerably by the changes in firing, falling when the firedoor is opened for fresh firing.

In this arrangement no additional space is required for the superheating apparatus, the whole being contained within the ordinary smokebox, without any alteration of the boiler or any interference with its construction; the only external addition being the stop valves communicating with the apparatus. This apparatus can therefore be readily applied to ordinary marine boilers, without requiring any alteration beyond the extra connexion and stop valves, and without interfering with any of the arrangements of the engines or boilers; and the important saving of 20 to 30 per cent. of the fuel can be thus effected, without incurring any risk of trouble or delay from the superheating apparatus. In case of any failure of the apparatus, it will be seen that it is only necessary to shut one set of stop valves and open the other.

The writer would observe in conclusion that there are various plans adopted by different engineers for superheating the steam, many of which have been applied by the inventors, and in many cases with considerable success. Amongst these may be named those of Mr. Wethered, Mr. Partridge, and Mr. Pilgrim, who have done much lately to establish the value of the system by practical application.

The CHAIRMAN observed that the trial of superheated steam had been determined upon in the case of the vessel described in the paper, after the completion of the boilers; and the time being very short for fitting up the apparatus, he had to devise a means of accomplishing it without interfering with the work already done, and had consequently adopted the plan shown as the simplest arrangement and the quickest for construction. The apparatus was simply a work of repetition in the parts, the superheating tubes being all exactly alike, and fitted by machine work; the great object in view was to ensure against any risk of interfering with the efficiency of the vessel by failure or accident with the new apparatus, and to arrange the whole so that it could be readily disconnected and the work carried on exactly the same as before the application of the superheating apparatus.

He had not had an opportunity of trying any experiments with it himself, and did not consider the trial at present made a fully conclusive one as to results; but the vessel had been three months working since the apparatus was applied, part of the time without the apparatus for the purpose of comparison, and a pretty satisfactory proof of its success was that the engineers were very glad to get the apparatus in again; and there was found to be a reduction of 20 per cent. in the consumption of fuel when the apparatus was used. He had tried one approximate experiment with the apparatus before the vessel left this country, by graduating the opening of the injection cock of the condenser, and observing the extent of opening required for working with and without superheated steam; and he found that little more than two thirds of the quantity of injection water was required when the steam was superheated, showing that a much smaller quantity of steam must have passed through the cylinders into the condenser, with a corresponding saving in consumption of fuel in the boilers.

A difficulty was anticipated at first in keeping the joints all permanently tight throughout the apparatus, but none whatever was experienced, and there had been no leak since it was put to work; the tubes were all made a thorough mechanical fit in the tube plates so as to be perfectly steam-tight, and they were not exposed to any strains from expansion and contraction, as the end chambers were free to move with the tubes, and the whole was of one material. It was an

important point in anything of the kind to have a thorough good job made at first, and several of the attempts at applying superheated steam had been unsuccessful from failure of the apparatus in mechanical points, causing objections to be felt to superheating that did not really apply to the principle itself, but only to defects in the mode of carrying it out.

Mr. W. S. Ward thought the paper that had been read was a most interesting one, showing a valuable example of carrying out an important principle judiciously and carefully. The importance of superheating the steam was pointed out by theory, which showed the great loss in the power ordinarily obtained from steam compared with its theoretical power; but it was often difficult to realise in practice theoretical advantages. As the quantity of latent heat taken up in evaporating water was a very large proportion of the whole heat supplied, it appeared more advantageous to apply further heat in superheating and expanding the steam, than in evaporating more water; the ratio between the latent and the sensible heat being nearly 4 to 1. And in the case of expanding steam in a cylinder, a lowering of temperature was produced by part of the sensible heat in the steam becoming absorbed as latent heat for effecting the expansion of the steam; but if the steam were a little superheated originally, the extra heat would allow of the expansion being effected without cooling the steam below its natural temperature at the original pressure. He hoped this important subject of superheating steam would be carried on to a further extent, and that all the circumstances and laws of its action would be fully investigated.

Mr. H. W. Harman enquired whether there had been any opportunity of ascertaining what increase in volume of the steam was effected by the superheating, and whether there was any difference in the pressure; and whether the working of the boiler was at all affected by the superheating by any back action of heat being communicated to the steam in the boiler under any circumstances.

The Chairman replied that the pressure was kept the same, as it would be regulated in both cases by the load on the safety valves, which was not altered; the effect of the superheating could therefore be only to increase the volume of the steam by the expansion due to

the increase of temperature, so that a greater quantity of steam at the same pressure would be supplied to the engines from the evaporation of the same quantity of water in the boilers.

Mr. J. F. SPENCER remarked that a great difference sometimes existed in the temperature of the steam in different parts of the same boiler when superheated; he remembered noticing in the boilers of a large steamer, which had high steam domes with the uptake flue passing up through so as to superheat the steam at that part, that the temperature of the steam in the top of the dome was as much as 340°, whilst it was only 260° in the boiler just below the dome.

Mr. E. A. COWPER observed that the pressure did not vary with the temperature; and whatever superheating took place, the effect could be only an increase in the volume of the steam and in its temperature, as it would be impossible for any difference of pressure to exist in the superheating apparatus, except indeed a slight diminution of pressure that would arise from the resistance of the small tubes to the passage of the steam. The first effect of the superheating would be the evaporation of all the moisture in the steam, as steam always left the water in a boiler in a more or less wet or damp state, from the mixture of minute particles of water with it, even when there was no sensible priming; it would then become perfect or dry steam, but at first would not be raised at all in temperature; but when the superheating was carried beyond that point, the temperature of the steam would be raised by all the heat added, and its volume proportionately increased, causing an increase in the total quantity of steam supplied at the same pressure and from the same evaporation of water. Steam was expanded by increase of temperature at pretty nearly the same rate as air and other gases: and since air at 32° was doubled in volume by an increase of temperature of 480°, steam at 20 lbs. per inch or 260° would be doubled in volume by 708° increase of temperature ($480° + 260° - 32° = 708°$); and a rise of 100° from 260° to 360° would consequently increase its volume 1-7th, causing an equal saving in consumption of fuel when the superheating was effected by using the waste heat of the smokebox. As the specific heat of steam was only about 3-4ths that of air, steam would require only 3-4ths the quantity of heat to be supplied to it to produce the same

rise of temperature; and partly for this reason steam was now used instead of air in caloric engines, since the same effect of expansion was thereby obtained with so much less supply of heat.

There was no doubt that in cylinders without steam jackets condensation of a portion of the steam took place at the beginning of the stroke, and a partial re-evaporation at the end, on account of the metal of the cylinder being colder than the fresh high pressure steam entering from the boiler, but hotter than the expanded steam in the cylinder at the end of the stroke; since the whole metal of the cylinder could not change in temperature twice in each stroke, (though the interior surface must do so), the temperature of the cylinder and piston must be an average of the temperature of the whole of the steam coming in contact with them. He had tried a direct experiment suggested to him by Mr. Appold, namely fixing a glass gauge tube in communication with the interior of the cylinder, the outer end of the tube being closed: at the beginning of the stroke the interior of the glass became quite dull with moisture, from condensation going on in the cylinder; but towards the end of the stroke the moisture was entirely evaporated and the glass became clear, showing that there was perfectly dry steam in the cylinder by that time. The cylinder was in fact a partial condenser at the beginning of the stroke, and a boiler at the end of the stroke; and if it were not for this boiling off of the condensed water at the end of the stroke, the cylinder would soon get very nearly to the temperature of the steam.

In an expansion engine without a steam jacket he had found by a comparison of the actual indicator figures with the theoretical figures which ought to have been obtained if no condensation had taken place in the cylinder, that the loss of power when cutting off the steam at $\frac{2}{7}$ stroke amounted to a loss of 11·7 per cent.

at $\frac{1}{5}$ stroke	19·6 per cent.
at $\frac{1}{8}$ stroke	27·2 per cent.
at $\frac{1}{11}$ stroke	44·5 per cent.

But when the cylinder had a steam jacket supplied with steam direct from the boiler, he found the actual indicator figure almost exactly corresponded with the theoretical figure, except that at the end of the stroke it was raised a little, about $\frac{1}{2}$ lb. in pressure above the theoretical

line, in consequence of the superheating of the expanded steam from the higher temperature of the metal of the cylinder. With steam in the jacket of the same pressure as that in the boiler he did not think there could be any condensation in the cylinder; for all that was requisite to prevent this was to keep up the metal of the cylinder at the temperature of the entering steam, by supplying the heat abstracted by exposure to the cooler steam during expansion, and that lost by radiation which was very small in a well lagged cylinder: the piston ought to have non-conducting surfaces or plates, and the cylinder ends should have steam jackets.

He was very glad the important subject of superheating steam had been so well taken up in the interesting paper that had been given by the President, and was confident that a still higher saving of fuel than the 20 per cent. mentioned in the paper would ultimately be effected by that means.

Mr. R. Morrison observed that the stop valves in the steam pipes of the superheating apparatus shown in the drawings gave the means of mixing the superheated and the ordinary steam, and he enquired whether any trial had been made of mixed steam in this case; also whether, if the boilers had not been already made before the addition of the superheating apparatus was contemplated, they might not have been made proportionately smaller, as the superheating apparatus formed in effect an addition of 2¾ square feet of heating surface per nominal horse power, increasing the original proportion of the boilers from 19 to 21¾ square feet per horse power.

The Chairman replied that the superheating apparatus must certainly be regarded as a portion of the heating surface, and some reduction might consequently be made in the boilers on that account, besides the reduction due to the saving effected in the quantity of water to be evaporated in doing the same work. In reference to the question of mixed steam, he had not tried any experiment on the subject, and did not see that as regarded the final effect it mattered how the steam was heated, provided the temperature of the whole steam that entered the cylinder was raised the 100° required to prevent any portion of it being cooled below its natural temperature whilst passing through the cylinder; and it seemed to him that the

best way of attaining that object was to heat the whole steam on its passage to the cylinder.

Mr. R. Morrison asked whether any higher temperature had been tried, or was considered likely to produce a further advantage; also whether from the experience of the working of the present apparatus any smaller size of heating tubes would be considered preferable; and whether there was found to be any inconvenience in cleaning out the boiler tubes, on account of the superheating apparatus being fixed in front of them.

The Chairman replied that he had tried a temperature of only 360° to 370° at present, but from the results obtained his opinion was in favour of that temperature with the pressure of 20 lbs. per inch that was used in marine engines, as accomplishing all the important portion of the saving to be obtained, and keeping quite clear of any risk of the increased wear in the cylinders and pistons to which they were exposed with higher temperatures. The size of the tubes used appeared to be satisfactory; and as the total area of steam passage had to be maintained, a smaller size of tubes would have involved a greater number of tubes and more workmanship, without perhaps giving any advantage. In the case of tubular boilers the superheating tubes were limited in size and arrangement by the tubes in the boiler, as they had to be placed in corresponding intermediate rows to allow of cleaning the boiler tubes, which could be readily done through the intermediate spaces.

Mr. D. Joy enquired what difference was shown by the indicator diagram in the expansion curve when the superheated steam was used.

The Chairman replied that the indicator diagram was fuller, the expansion curve not falling so rapidly at the commencement as when the steam was not superheated.

Mr. R. B. Longridge asked whether any material difference was caused in the temperature of the uptake flue.

The Chairman had not tried the actual difference of temperature, but there was a very marked change in the temperature of the stoke hole, which was kept much cooler than before.

Mr. R. Morrison asked whether any difference had been observed in the wear of the engines with the use of the superheated steam.

The CHAIRMAN replied that no difference had yet been perceived; the results were of only three months' experience at present, but there was no probability of any effect being produced in that respect by so moderate a temperature as the one that had been adopted.

Mr. D. ADAMSON said he had used steam of 150 lbs. per inch, which would be about 370° temperature, and found no cutting of the cylinder or injurious effect arising from the high temperature after 4 years' constant work, during which the piston had not been examined more than four times: the piston worked at a speed of 280 feet per minute, and had metallic packing, which continued quite smooth and in good working order. He recommended using high pressure steam direct to a high pressure cylinder, and exhausting after moderate expansion to a low pressure condensing cylinder, heating the low pressure steam up to the temperature of the high pressure steam, say 370°, in the passage between the cylinders and in the second cylinder; thus deriving all the advantage of increase of bulk due to the superheating of the expanded steam, and of non-condensation between the cylinders; no difficulty being occasioned in the working of the piston from the high temperature in the second cylinder any more than in the first.

Mr. G. A. EVERITT said he had made a trial of superheated steam in a pair of 60 horse power engines at his works at Birmingham, under the advice of Mr. Cowper, which had proved very satisfactory, and a decided saving of fuel was effected by the superheating, although it was applied to a limited extent and in only one of the engines, a condensing engine worked by the exhaust steam from the other engine; this steam was passed into an intermediate receiver, having a steam jacket heated by the high pressure steam from the boiler, so as to superheat the steam supplied to the condensing engine.

Mr. R. MORRISON said he had made a trial of 60 lbs. steam superheated to a temperature of 400°, in a condensing marine engine of 100 nominal horse power, expanding through 5-6ths of the stroke; the cylinder had a 3 inch space round as a steam jacket supplied with the ordinary steam from the boiler, and a 2½ inch thickness of felt and wood lagging upon the steam jacket. The indicator diagrams from the engines were very excellent, and almost identical with the

theoretical expansion curve; but he thought the superheating had been carried rather too far, for the piston began to cut and the oil was used up very rapidly in the cylinder.

Mr. E. A. Cowper considered that oil was not suitable for lubrication with highly superheated steam, as it was burnt up or charred rapidly at such high temperatures: 360° was certainly quite a safe temperature, and he thought even 400° might be made use of if oil were not employed for lubrication. He had known an instance where 100 lbs. steam was used in a double-cylinder engine, expanded 12 times, and the high temperature of the 100 lbs. steam (about 340°) was kept up in both steam jackets; in that case there was found to be some cutting of the piston, but oil was used for lubrication. He had suggested a plan for preventing this by keeping the cylinders about 100° cooler than the steam, so as to cause a slight condensation upon the surface to keep it damp and so prevent its cutting with the friction of the piston: he had tried an experiment which proved that even with very hot steam the surface could be kept damp if it were 100° lower than the temperature of the steam.

The engines that had been referred to by Mr. Everitt were two of 60 horse power working at right angles, the first high-pressure working with 35 lbs. steam, and the second a condensing engine worked by the exhaust steam from the first; and as it was not convenient to alter the arrangement of the engines, he placed a large receiver between the two, more than equal to the capacity of the second cylinder, in order to reduce the back pressure in the first cylinder during the portion of the stroke that the second cylinder was not open to receive the exhaust steam, and the pressure of steam in the latter was also limited by a safety valve on the receiver. This receiver was enclosed in a steam jacket supplied direct from the boiler with a temperature of about 282°, and the average temperature of the steam in the receiver was 231°, so that the steam supplied to the condensing engine was to some extent superheated.

Mr. A. Fryer thought the full advantage of superheating would be obtained by simply carrying it so far as to ensure that no condensation whatever should take place in the cylinder, and the steam should be in its natural state to the end of the stroke; for though there

must be an advantage to be gained by carrying the process further, so as to have superheated steam acting throughout the stroke, thereby obtaining the additional supply of steam that was produced by its increase in volume arising from increase of temperature, yet he conceived that the fuel used to produce this effect would have produced a greater mechanical effect if applied to the boiler to generate more steam.

Mr. H. Maudslay considered the subject was one of great practical importance, and he was very glad it had been so ably taken up by the President; there was no doubt that an important economy of fuel would result from carrying out the principle judiciously. He had heard of experiments recently tried in one of the West India Mail Packet Company's steamers, at the suggestion of their engineer, the late Mr. George Mills, in which about one third of the steam was superheated about 30°, and then mixed with the remaining wet steam at the cylinder; the result was found to be beneficial, though much less marked than the results described in the present paper where the whole of the steam was superheated. He was very glad to hear the present satisfactory results obtained by carrying out the plan of heating the whole steam in so complete and simple a manner. Failures had arisen in many previous attempts, where only a portion of the steam was heated, from too small an area of passage being given, sometimes only a single small pipe communicating with the steam chest, so that only a small proportion of the steam could pass through the superheating apparatus and no sensible result could be obtained; many failures had also occurred from defects in the mechanical arrangement causing stoppages from leakage and burning of pipes and joints, which had occasioned doubts as to the practicability of carrying out the principle satisfactorily in work. He trusted the present successful application would be followed up by general attention to the subject, and a thorough trial of the principle to ascertain the best mode for its application and the extent to which it could be advantageously carried out.

Mr. B. Fothergill observed that in the use of superheated steam caution was requisite as to the effects of the high temperature, not only upon the working faces of the cylinders and valves, but upon the surface of the steam pipes when of iron: for he had known a case where

superheated steam was tried in a mill in Manchester with decidedly good results as to economy of fuel; but probably from carrying the superheating beyond the point that had been recommended, so much oxidation of the pipes from overheating had occurred that the condensed water from the engine, which was employed for manufacturing purposes, became impregnated with rust and spoiled a large quantity of goods.

Mr. J. F. Spencer thought the paper that had been read on the application of superheated steam was one of great value and importance, particularly on account of the thoroughly practical way in which the subject had been considered and the excellent arrangement made for effecting the trial; avoiding all risk of carrying the process too far, and simply aiming at first at effecting the definite object of preventing any loss from condensation in the cylinder and ensuring perfect steam throughout the stroke. The subject was now one of great importance, and he hoped it would be resumed at a future meeting, with the discussion of further results from more extended trials.

A vote of thanks was passed to the President for his paper, on the motion of Mr. H. Maudslay seconded by Mr. E. A. Cowper.

The following Paper was then read:—

DESCRIPTION OF FRYER'S APPARATUS FOR FILLING LOCOMOTIVE TENDERS WITH WATER.

By Mr. JAMES FENTON, of Low Moor.

Dr. Papin, the celebrated French precursor of the many inventions connected with modern steam power, demonstrated as early as the year 1700 the practicability of raising water by the direct action of steam pressure on its surface; and this system is still adopted with complete success for raising saccharine fluids in most sugar houses throughout the world. The method of filling locomotive tenders with water where the supply is below the level of the railway, recently invented by Mr. Alfred Fryer of Manchester and forming the subject of the present paper, is in fact an adaptation of Dr. Papin's simple contrivance of 160 years ago.

The apparatus is shown in Figs. 1 to 4, Plates 41 and 42. It consists of a wrought iron cylinder A of 1500 or 2000 gallons capacity, placed upright beneath the surface of the supply water B, Fig. 4, which may be from 10 to 120 feet below the level of the railway. To reduce the amount of condensation, the cylinder A is surrounded with brickwork, and a space of 2 inches between the brickwork and the cylinder is filled with clay to prevent any water from getting to the outside of the cylinder. The cylinder contains a wrought iron float C fitting it easily and sliding on a centre guide rod. The supply water enters through the self-acting inlet valve D, Fig. 4, of about 75 square inches area, and is discharged from the bottom of the cylinder through the pipe E leading to the engine water-crane F. A steam pipe G is attached to the top of the cylinder, leading to two pillars H, Fig. 1, placed a few yards distant on each side of the crane F and near the line of rails, which are provided with flexible pipes I having bayonet joints for coupling to the locomotive boiler. When a tender is drawn up to be filled, the engine driver couples one of the pipes I to the boiler, as shown in the plan, Fig. 2, and turns on the steam, which passing into the water cylinder A presses on the float C and forces the

water up through the crane F into the tender with great rapidity, so that the tender is filled in about half the usual time.

In order to prevent the steam now contained in the upper part of the cylinder A from blowing out violently into the atmosphere when the flexible pipe I is disconnected, a valve is placed in the top of the pillar H opening inwards, which allows a free passage for the steam to enter the cylinder, but when the pipe I is uncoupled the steam can only escape slowly through a small hole drilled in the valve. A hanging valve K, Fig. 4, is placed between the two branches of the steam pipe G, which prevents the steam entering through one of the pillars H from blowing out direct through the other instead of passing down into the cylinder A. As the steam escapes from the cylinder a fresh supply of water enters it through the inlet valve D, the cylinder being placed below the surface of the supply water. The valve D is contained within a well L, and the supply water is admitted through the valve and grating M, by which it can be stopped back out of the well at any time to allow of examining the valve D; or the valve itself can be detached and drawn up to the top of the well, being slid down to its place upon long guide rods and secured by long screwed bolts that can be reached from the surface. The float C is strengthened against collapsing by circular stays; and a small tube N is inserted in it reaching almost to the bottom, so that if any water should get into the interior of the float through a defective joint it is expelled through the tube as soon as the pressure of steam is removed from the outside of the float after filling a tender.

Fig. 3, Plate 42, shows the arrangement of the apparatus when the supply of water is obtained from a reservoir at the foot of an embankment; and the plan is equally applicable where the supply is taken from a well considerably below the level of the ground or from running water.

In this plan of raising water by the direct action of steam pressure it might be expected that the condensation of steam in the water cylinder would be so considerable as to interfere seriously with the working of the apparatus; but it must be borne in mind that the larger the cylinder the smaller is the extent of surface presented for

condensation in proportion to its content; and it has been proved by experiment that this is not a serious objection in the size of the present apparatus; while the friction and waste of power involved with the pumps and engines now in use are obviously saved. In order to ascertain whether a locomotive boiler can afford to lose the amount of steam requisite to raise the water, especially where the lift is from 50 to 60 feet high, a boiler has been constructed of 141 gallons capacity, 69 per cent. of which was filled with water, connected by a flexible tube with a water cylinder holding 131 gallons, the arrangement being in all respects similar to that already described; the discharge water pipe from the cylinder rose 60 feet perpendicularly, but had valves at various lower elevations. The water pipe was 4 inches diameter inside, and the steam pipe 1½ inch diameter, and the area of steam way in the tap 1·83 square inch. A number of trials were made, in each of which 131 gallons of water were raised, the average height of lift being 52 feet, and the average pressure of steam in the boiler 56½ lbs. per square inch: in order to guard against too rapid a generation of steam and to approximate to the condition of a locomotive when standing at a station, the damper remained closed during each trial. It was then found that the loss of steam pressure in raising the 131 gallons of water 52 feet high was only 4·2 lbs. per square inch, and the time required 32 seconds. When the damper remained open, the steam was generated more rapidly than it was used, and the pressure then rose during each trial. Hence a locomotive just arrived at a station will always have sufficient steam to spare to refill the tender; and this will consequently be effected at the entire saving of the pumping engines, pumps, and buildings at present necessary, while the heavy expenses now incurred of attendance, repairs, and fuel are dispensed with.

With this apparatus there is no difficulty in working during frost, the crane and pipes being kept always empty, and the water cylinder below the ice; thus removing the danger of the pipes bursting, and obviating the necessity of keeping them thawed by the application of fires as in the case of the present water cranes. This is a consideration of no little importance, especially in Canada and other countries subject to severe and protracted frosts. The steam that is condensed

in forcing up the water is not entirely lost, as it serves slightly to warm the water which will shortly supply the boiler. It has been computed that the cost in fuel of raising 1000 gallons of water 50 feet high by this process is less than one halfpenny; and the plan is therefore recommended by economy, great simplicity, and rapidity of action.

Mr. Fenton observed that Mr. Fryer, the inventor of the apparatus, had had the plan in regular work for some years at Manchester for raising liquids in a sugar manufactory; it was working very satisfactorily, and had proved a convenient and advantageous mode of applying steam power for that purpose.

Mr. A. Fryer said he had been led to this plan by difficulties experienced in raising continually large quantities of saccharine fluids, of a specific gravity of about 1·3, which had to be raised a height of 60 feet to the top of the sugar manufactory. Cranes were previously used to lift the bags of rough sugar to the top of the building, but this was found to be a slow and expensive process when a large amount had to be conveyed; and pumps were then employed for the purpose, the first process of dissolving the sugar in hot water being performed at the bottom of the building and the liquid then pumped up to the top. But the pumps were found to be rapidly worn and cut by the large quantity of sand, pieces of cane, and other rubbish that was mixed with the rough sugar, and no form of pump was able to stand the work. He then tried the direct application of the steam pressure to force up the liquid through a pipe, and found it so completely successful that the plan was adopted for the whole of the work. The dissolved sugar was put in a large close vessel, like a circular boiler, 6 feet diameter, with a delivery pipe 4 inches diameter extending from it to the top of the building, a height of 60 feet; and steam at 40 lbs. per inch pressure was let into the upper part of the vessel, and pressing upon the surface of the liquid forced it instantly up the delivery pipe, the lower end of which reached to the bottom of the vessel inside. The process was effected with great rapidity, the solid refuse lying at the bottom of the vessel being swept clean out together with the liquid. A quantity of 20,000 gallons per day was regularly raised in this way,

and the solid matter carried up besides amounted to several tons per day. The vessel was re-charged by condensing the steam in it by a jet of cold water upon the outside, and opening a communication with the vat in which the sugar was dissolved; the vessel then became rapidly filled, and the process of letting in the steam and expelling the contents up the delivery pipe was directly repeated. There was found to be but little waste of steam in this process, although no float was used in the vessel and the steam was admitted direct upon the surface of the liquid; for a film of boiling water was immediately formed upon the surface of the liquid by the condensation of a small portion of the steam, which acted effectually as a non-conducting diaphragm cutting off the communication with the colder liquid below, since there was no circulation to convey the heat downwards.

He had also made a trial of the same plan for raising water from a well 65 feet deep upon the works, in which the pump was sometimes under water so that the valves could not be reached for repairs, and the pump was consequently stopped working; and he had succeeded in raising 100,000 gallons of water per day from the well by that means. In this case the rising main from the pumps which was 18 inches diameter had a second pipe 4 inches diameter inserted within it, extending nearly to the bottom and having a valve at the bottom opening upwards; the space between the two pipes was closed at the top with a steam-tight joint, and steam of 40 lbs. pressure was admitted to it from an adjoining boiler. This steam expelled the water from the space between the pipes, driving it up the centre pipe; and on shutting off the steam a fresh supply of water entered this space by condensation of the steam, and was again expelled up the centre pipe by repeating the process.

In order to ascertain whether in the case of filling locomotive tenders there would be any risk of difficulty from want of sufficient steam in the engine boiler to serve for raising the water, he had tried some experiments with a small boiler disconnected from any other work, raising the water by the steam pressure from a close vessel up a vertical stand pipe, which had cocks fixed into the side at different levels that could be opened successively for discharging the water. He found that the water was discharged at 60 feet height with a

pressure of steam in the boiler of 27 lbs. per square inch, which was only slightly above the pressure required to balance the column of water. The quantity of steam required was found to be so small that a supply of water sufficient to fill a locomotive tender was easily raised with the boiler fire checked and the damper kept closed, to correspond with the condition of a locomotive standing at a station. In applying this plan for filling tenders, his object was to employ the power available in the locomotive engine for raising the water direct, instead of requiring the erection of fixed pumping machinery and engine power at each station.

Mr. S. Bastow thought the plan possessed many advantages, and would be very suitable for the purpose intended; it had great simplicity and freedom from liability to derangement, which were important points in water supply for railway trains; and the security from damage and stoppage by frost would be a great gain: also the saving in first cost would be very considerable where stationary engines had now to be employed for pumping.

Mr. R. P. Williams had experienced much difficulty with the ordinary railway water cranes, which caused much trouble and expense in keeping them in working order. He was struck with the simplicity of the plan now described, and thought it would be a great advantage and be very applicable for road stations where the expense of working pumping engines was more particularly objectionable. The first cost must be much lessened by saving machinery and pumping engines, and there would be a great saving in the present cost of repairs and maintenance.

Mr. Fenton thought there would not be any practical difficulty in the working of the apparatus, and the locomotive engines would be sure always to have steam enough when on the line for raising their own supply of water. The plan would he thought be generally applicable, except at some terminal stations where pumping would remain as at present; and the result would be a considerable saving in expense both of construction and of working.

The Chairman proposed a vote of thanks to Mr. Fenton and Mr. Fryer for the paper, which was passed.

The following Paper was then read:—

ON THE CONSTRUCTION AND DURABILITY OF STEAM BOILERS.

By Mr. BENJAMIN GOODFELLOW, of Hyde.

The object of this paper is to communicate some circumstances and changes that have been observed by the writer to take place in the size and form of boilers at different temperatures, which affect considerably their strength and durability by causing derangement and wear and tear to a much greater extent than he believes is generally supposed. His attention was first strongly drawn to this subject some years ago in reference to a large multitubular boiler that he constructed, 23 feet long and 6½ feet diameter, with 131 tubes 11 feet long and 3 inches diameter each; and two similar boilers but of smaller dimensions with 9 feet tubes. A short time after these had been put to work, it was found that several of the tubes began to leak at both ends, although they had previously been proved up to 120 lbs. per square inch with water pressure, when all was good and tight, and the steam pressure they worked at was only from 50 to 55 lbs. After this leakage had been made good, it took place again in a few weeks; and this was repeated several times, both in the large and small boilers, but not to the same extent in the small ones. This led the writer to conclude that the cause was the elongation of the tubes by their being heated to a greater extent than the casing of the boiler; and this defect appears to him a serious objection in multitubular boilers with straight tubes of considerable length.

In the construction of flued boilers of considerable length, say from 20 to 36 feet long, the writer at first adopted the plan of increasing the diameter of the flue, so as to increase the heating surface and diminish the quantity of water; bringing the flues nearer to each other, in the case of the two-flued boiler, and closer to the sides of the boiler, as shown in Figs. 6, 7, and 8, Plate 44, in which the flues are made as large as can be got in. After a number of these had been got to

work, several of them gave way transversely about the middle seam at the bottom, especially in cases where the boiler had been blown off for cleaning and cold water then turned in to cool it; the effect of which was that the bottom of the boiler instantly contracted in length, while the flues retained the same length or nearly so as when working, until the water came in contact with them, thereby necessarily throwing a great and undue strain upon every seam of the boiler, especially on the lower side in consequence of the flues being so near the bottom of the boiler. The writer therefore concluded that it was wrong to increase the diameter of the ends of the flues, as this rendered the ends of the boiler much more rigid and less yielding to the expansion and contraction of the flues and casing, which do not take place in both simultaneously or to the same extent. In a boiler 30 feet long the actual expansion of the barrel of the boiler amounts to nearly 1 inch in length; and when fired in the flue, the latter is elongated ¼ inch more than the casing, in consequence of its being at so much higher a temperature. The evil effects of this expansion and contraction are further augmented by the ordinary use of gusset stays, by which the ends of the boiler are stiffened and rigidly connected to the barrel, as shown in Fig. 9, Plate 44. The circumstance of the boilers giving way in the middle of their length rather than in any other part was owing in the writer's opinion to their being supported on a longitudinal centre wall which divided the flues, or on two walls, as shown in Figs. 2 and 3, Plate 43; when full of water the boiler would weigh from 38 to 40 tons, and consequently there would be a great friction on the wall when the boiler was contracting; and the strain thus produced in pulling the two ends of the boiler nearer together is concentrated at the middle of its length, in addition to the strain arising from the resistance occasioned by the rigidity of the flues and gusset stays.

In order to obviate these difficulties in flued boilers and to provide for expansion and contraction taking place without much injury to the material or workmanship, the writer has been led to adopt the construction of boiler shown in Fig. 1, Plate 43, representing the end portions of a two-flued boiler 30 feet long. In this construction the ends of the flues are tapered and reduced in diameter, for the purpose

of giving a greater amount of elasticity to the ends of the boiler; and with the same view the gusset stays are dispensed with, so that the ends are not connected in any way with the casing except by the angle-iron ring that unites the two together. The same plan may be carried out in a single-flued boiler either by tapering the ends of the flue or placing it nearer the centre of the boiler. The ends of the boiler are strengthened independently by means of T iron or "fish-back" girders AA, rivetted on each end between the casing and the flues, as shown in Fig. 5; and there are no longitudinal stays between the two ends beyond those supplied by the flues and casing, each end plate being treated as an independent transverse girder supported round its edge. In order to strengthen the bottom of the boiler at the middle against the strain produced in contracting by the friction of the longitudinal walls on which it is supported, two longitudinal strips of angle iron or T iron BB are rivetted on the inside at about 3 feet apart, extending about two thirds the length of the boiler, as shown in Figs. 1 to 3; these strips are rivetted in close contact with the plates, so as to have the same temperature as the plates under all circumstances. The writer has also adopted for some time a plan of strengthening flues of large diameter against collapse by means of rings of T iron or angle iron CC rivetted at suitable intervals round the outside of the flue at the joints, as shown in Fig. 5. In these joints the two ends of the boiler plates are not brought together, but are left with a space between them equal to the thickness of the outer rib of the T iron, as shown in Fig. 4, Plate 43, whereby a joint is obtained having no greater thickness of metal than a double plate at any part.

The absence of longitudinal and gusset stays in this construction of boiler does not leave the ends less strong to resist explosion than the other parts of the casing: for taking the whole circumference of both flues and casing, the sectional area of plate resisting the pressure on the ends of the boiler is $4\frac{3}{4}$ times greater than that resisting the lateral pressure in the casing; and in the upper half of the ends, where the pressure acts upon the greatest proportionate area, producing the greatest longitudinal tension, the resistance is $3\frac{1}{2}$ times that offered to lateral explosion; while in the lower half of the ends, where there is the least proportionate area for the pressure to act upon, the resistance

is $6\frac{1}{2}$ times greater than the lateral resistance. The fact that flued boilers generally explode endways by failure of the lower part of the ends or casing, the very part which has been seen to be originally the strongest, proves that the strength of the plates at that part becomes greatly injured by the excessive strains arising from unequal expansion and contraction of the flues and the casing of the boiler.

The action of expansion and contraction with this construction of boiler is shown in Fig. 5, Plate 43, the actual amount being exaggerated for clearness of illustration. The dotted line shows the form assumed by the ends of the boiler when in full work with a good fire, the flue being then considerably longer than the casing, causing the ends to be bulged outwards. The full lines show the reverse condition, with the ends bulging inwards, in consequence of the flue contracting more than the casing, which takes place when the fire is drawn out and the door and damper opened, the flue then cooling more rapidly than the casing of the boiler which is surrounded with hot brickwork. In the ordinary construction of boiler with rigid ends supported by gusset stays this deflection of the ends is prevented from taking place; and consequently when the ends and casing are sufficiently strong, the elongation of the flue under expansion produces a strain of compression which has the effect of slightly corrugating or buckling the plates of the flue, as shown in Figs. 6 and 7, Plate 44, thereby materially assisting in causing the flue to collapse. At the same time a strong tensile strain is thrown upon the casing, tending to tear it across, particularly at the bottom of the boiler, the flues being much nearer the casing at that part than at the top: the same strain also tends to tear the ends away from the gusset stays, and often causes one or two of the rivets of the stays nearest to the flues to begin to leak after the fire has been put in.

In the case of plain cylindrical boilers with hemispherical ends and without any flue, the effects of expansion and contraction are shown in Fig. 10, Plate 44. Some of these boilers came under the writer's observation lately, which were 36 feet long and $6\frac{1}{2}$ feet diameter, resting on brackets fixed to the sides. In Fig. 10 the dotted lines show the boiler when at work with a good fire under it, the

bottom being then elongated by expansion, curving the boiler slightly upwards at the ends. When the boiler was stopped for cleaning, it was the practice after blowing off to run in some cold water immediately to assist in cooling it, which had the effect of suddenly contracting the bottom, curving the ends of the boiler downwards, as shown by the full lines, and tending to tear the boiler across at the bottom. After these boilers had been at work five years they began to tear in the bottom seams in the same manner as previously described in the two-flued boilers, with the exception that the failure did not always take place near the centre, but at different places in each of them, as there was no wall underneath the boiler in this case and therefore no strain of friction to be overcome in contracting.

The durability of boilers is greatly affected by the changes of temperature to which they are exposed as above described. Boilers have frequently exploded from simple internal pressure of steam, which have previously been proved to be capable of standing twice the pressure they have exploded at; and in the writer's opinion this has arisen from different parts having been materially but imperceptibly weakened by the strains resulting from successive changes of temperature: many instances might be brought forward to show the injurious action occasioned by this cause. Where the changes of temperature have been less frequent, the durability of the boiler has proved greater; and the writer has recently seen several two-flued boilers 30 feet long which had been at work about eight years without showing any signs of failure: these boilers had been working night and day without stopping, except once every six or eight weeks for cleaning, but as a consequence of that constant working they had not undergone the same number of changes as if they had been cooled more or less every night and at every week's end during that time. The writer has no doubt that by making proper provision for such changes going on without damage to the material or workmanship, a considerable amount of wear and tear might be prevented, and boilers would retain their strength with safety and continue in good working order for more than double the length of time that has hitherto been the case in such boilers made without this provision.

Figs. 11 and 12, Plate 44, show a multitubular boiler that was constructed by the writer some time ago with arched tubes instead of straight tubes, with the view of obviating the defects experienced in the ordinary construction from leakage at the ends of the tubes in consequence of expansion; but the mechanical difficulties attending this plan and the extra draught required have at present proved impediments to its further application for large stationary engines.

Mr. R. B. Longridge could confirm the observations made in the paper as to the frequent injury caused to boilers by the effects of unequal strains upon different portions; but he did not agree with the opinion expressed that the construction of boiler proposed would be free from this source of injury. There was no doubt that great mischief arose in many boilers from imperfect circulation of the water. If perfect circulation could be obtained, a uniform temperature throughout the boiler would be preserved, and these evils obviated. In two-flued boilers generally it was a great defect that the water spaces were made exceedingly small, and the descent of the water past them was opposed by the rising current from the heated sides of the flues, so that the only place where the water could descend was at the back end where coolest, and in a boiler of 30 feet length this downward current was not able to reach the front end: plates had been put into the boiler sometimes to divert the currents of water and cause more regularity of circulation, but he doubted whether with much success. When a couple of 3 feet flues were put into a 7 feet boiler, 3 inch water spaces only could be obtained; and although there was no doubt a better combustion in a large flue, yet this involved the sacrifice of the proper width of water space for ensuring due circulation in the boiler, which was a point of greater importance.

He did not agree with the mode proposed for staying boilers, and did not think it was at all advisable to dispense with both longitudinal and gusset stays; he considered that the end should not be left dependent only upon the rivetting to the cylindrical shell and the flues. The girder ends of the boiler would no doubt be strong enough so long

as the flues held good; but if the flues got seriously overheated at any part and fracture ensued, which was an accident that could not be absolutely guarded against, the boiler end might then give way on losing the support of the flues. In the case of boilers set upon a centre bearing wall, he did not see how the friction upon the bearing could cause such strain in expanding and contracting as sensibly to affect the durability of the plates; but the best plan of setting such boilers he considered was to support them upon cast iron saddles, in such a manner as not to be dependent for support on the brickwork forming the flues. An objectionable action was caused when the fire was not placed in the boiler flues but below the boiler, for in that case there was a continued current rising at the sides, causing a descending current in the middle between the two flues, which made the deposit all accumulate in the triangular space between the flues and immediately over the fire; in many such cases the plates over the fire became overheated in consequence, and fractured or strained at the joints.

Mr. Goodfellow considered the mode of fixing boilers on cast iron saddles was very good, and preferred it where a centre wall was not required for division between the flues. In respect of securing the boiler ends, he remembered a case where the end plates were increased from $\frac{1}{2}$ to $\frac{3}{4}$ inch thickness on account of the boiler leaking at the ends; but the bottom had then torn asunder, and he had suggested tapering the ends of the flues to a smaller diameter so as to increase the area of flat plate at the boiler end, and substituting a thinner plate for the purpose of getting more elastic action in the end plate: this had entirely removed the difficulty, and the boiler had continued at work for $1\frac{1}{2}$ years since then without any failure. He had found by carefully measuring the end of a two-flued boiler 28 feet long that the front end plate was pushed outwards $\frac{1}{8}$ inch in the centre, making it convex, each time the steam was up, and it gradually came back again on the boiler cooling; the back end of the boiler was not accessible for measurement, being within the brickwork, but both ends must have sprung nearly alike in order to cause the bulging, making altogether $\frac{1}{4}$ inch alternation in length of the flue, constantly going on in the working of the boiler. It appeared to him then that as this action could not be prevented it was the best course to allow the end plates

to yield to it, by leaving them elastic and not hindering them from springing.

Mr. S. Bastow thought there was no doubt that much had to be done in the construction of steam boilers to remove the imperfections now existing. The two-flued Cornish boiler was certainly an excellent one and appeared to be generally considered the best where compactness was required; but there was still something further to be desired, and he thought an improved construction would ultimately be adopted. The plain cylindrical boiler with convex ends was no doubt the best for durability, since its form gave rise to no unequal and varying strains, and no staying was required; if 20 years' experience were taken, the general result as to durability would be in favour of the plain cylindrical boiler: though it was of course not quite so good in economy of fuel, and where economy of space and compact setting were necessary it was not suitable. Perhaps the object might be gained by some combination of a number of cylindrical boilers of small size, arranged side by side, so as to obtain a large extent of heating surface without incurring the disturbing strains to which flued boilers were exposed; he thought the subject was a very important one for further investigation and trial.

Mr. J. F. Spencer considered that in marine boilers a great amount of injury and deterioration arose from want of sufficient attention to the unequal strains they were subjected to, the construction being too rigid or too much the reverse. There were also great defects in the imperfect circulation of the water, and in the very confined space between the tubes in multitubular boilers: the evils resulting from the latter were very serious, as the water was prevented access to the tubes, and the steam generated over the furnaces could not escape readily to the surface. He had known two boilers in which there was ½ inch difference in the tube spaces, with a difference of 50 per cent. in durability in favour of the wide-spaced boiler, although in other points of construction the boilers were similar. A space of 1 inch between the tubes was generally allowed, but an incrustation of ⅛ inch was formed upon the tubes after a time, leaving the spaces only ¾ inch; in locomotive boilers the case was still worse, the spaces being only ½ or ⅝ inch to begin with.

Mr. H. W. Harman said that, from his experience as chief inspector to the Manchester Association for the prevention of boiler explosions, he knew of no better construction than the cylindrical two-flued boiler, which was the one in most general use; but it was undoubtedly subject to the derangements pointed out in the paper from the effects of unequal expansion and contraction. An unequal strain was caused upon the end angle iron of the boiler from the flues being attached to the end plate so much below the centre: he had found many fractures of the end plates immediately over the angle irons of the internal flues, caused principally by the end plates not yielding sufficiently to the elongation of the flues. There was no doubt that if the plate were held too rigidly by gusset stays something would have to give way to the inevitable strain from expansion; but he could not agree at all with the plan proposed of dispensing altogether with gusset and longitudinal stays. The entire omission of stays would be the opposite extreme, and he thought they ought not to be abandoned without substituting something else; the angle iron which would then form the only tie between the end plate and shell was unavoidably a comparatively weak form of iron from the mode of its rolling, and he feared if such a plan were adopted great risk of accident from inferior quality of angle iron would ensue. He had examined boilers that had exploded, in which the whole of the angle iron had parted along the upper portion of the boiler end.

As to the strain along the bottom of the shell, he had found the addition of T iron strips along the bottom did not prevent this, and he believed it arose entirely from want of circulation in the water. The plan of a centre wall dividing the flue, with the boiler resting upon it, he considered objectionable; for any leakage of water trickled down to that point, and was absorbed by the centre wall like a sponge, acting as a constant source of corrosion to the boiler.

Imperfect circulation of water formed he believed the most serious defect in boilers; and in many of the two-flued boilers this was chiefly owing to their not having a sufficient water space between the flues and shell. He had long been convinced of the importance of ensuring a much better circulation of water being regularly maintained in boilers; and he contemplated effecting this by direct

mechanical means, by having a screw propeller of coarse pitch in the bottom of the boiler driven with a slow motion, to maintain a regular current of water throughout the boiler: he was about to make a trial of this plan, and thought it could be done by a simple contrivance, driven by the engine, not involving any objectionable complication: the object to be effected was one of great importance in the durability and economical working of boilers.

Mr. GOODFELLOW observed that, in regard to the angle iron forming the connexion between the shell and ends of the boiler, he had tried good angle iron with the severe test of hammering it nearly flat when cold, and found it stand without any failing; this was angle iron of good quality, but then only such material should be used in steam boilers, and he was satisfied that was the cheapest plan in the end. He did not see that any risk was incurred in trusting to the angle iron alone without gusset or longitudinal stays, for it was stronger than the plates of the boiler shell, having at least four times less to resist than the casing in the lateral direction: but this was of course dependent upon the quality of the iron, and he remembered a recent instance where a 7 feet boiler gave way in the testing with steam at 70 lbs. per inch pressure, causing great destruction of life and property, the angle iron stripping round the end of the shell, breaking through the rivet holes which had evidently been damaged in drifting the holes in the manufacture of the boiler, the material being of inferior quality; although a boiler of similar dimensions and thickness of plates, of good material, had been proved up to 80 lbs. per inch at the same place without any signs of giving way.

The damage that boilers received from unequal expansion often occurred suddenly he believed, and before any circulation of water could act to prevent it: the first moment of putting in the fire, or throwing in cold water immediately after the hot water had been let out, when the boiler was stopped for cleaning, caused a sudden expansion or contraction of different parts of the boiler, which overstrained the plates, and might in an instant reduce materially the ultimate strength of the boiler. He thought these accidental causes of injury occurred to a much greater extent than was generally

supposed; and from what he had observed he was led to conclude that in cases where the rivetted joints of the bottom of a boiler continued tight in regular working, they were caused to leak occasionally by the excessive strain brought on the bottom of the shell by the sudden expansion of the internal fire-flue.

Mr. W. Richardson had had experience of several kinds of boilers in use for a considerable time at Messrs. Platt's works at Oldham, both plain and flued boilers: several plain cylindrical boilers failed from the badness of the water, which caused a great deposit to form just over the fire, and the best plates were found to burn and fail at that part; but this had been completely remedied by putting a firebrick arch over the fire in such cases, extending as far as the bridge, in order to shield the boiler bottom from the direct action of the fire, and it did not interfere with the efficient working of the boiler. The Cornish boiler was found the best plan, and they preferred a single large fire-flue, 3 feet 10 inches diameter in a 6½ feet boiler 30 feet long; boilers of these dimensions had been working 5 years without any damage and had proved very satisfactory. The boilers were set upon four or five cast iron chairs 2 feet high, which would oscillate slightly with any longitudinal motion from expansion; a 4½ inch longitudinal wall was also used, but simply as a division between the flues, and the top course against the boiler was set in plumbers' putty to prevent absorption of water and risk of corrosion of the boiler bottom, and as an additional precaution this top course was taken out once a year and rebuilt, and the bottom of the boiler scraped and painted. For the internal flues Mr. Adamson's flanged joint was used, the plates being flanged out at every joint and rivetted together with a ring of plain iron between; he thought this was an excellent construction, giving such complete security against collapse of the flue, and the longitudinal expansion of the flue was eased by a slight springing of the flanges at each joint; where the joints were made at every 17 inches distance, the bulging action of the flue upon the end plate was so much reduced that no trouble or leakage was caused. They were now making a trial of steel plates $\frac{5}{16}$ inch thick for boilers at 100 lbs. per inch pressure, with double rivetted joints, and found them very satisfactory at present.

Mr. D. Adamson thought it was certainly advisable to have the gusset stays for support to the end plates of a boiler, and he did not see that anything could be gained by transferring all the action to one joint; but on the contrary there was this important disadvantage to be considered, that if a plate were bent backwards and forwards continually it might fail ultimately, though not subjected at any one time to too severe a strain; if all the buckling action were thrown on the end plate it would be simply a question of time as to its ultimate failure. On that account he thought gusset stays should not be abandoned, and they served also as a good support against collapse; he should also recommend longitudinal stays to be retained in addition, for relieving the strain upon the boiler end joints and the circular seams of the boiler shell.

In cases of intense firing and high pressure, thin metal was found the best suited to stand the heat, which was conducted more rapidly through it, and the overheating of the metal that occurred with thick plates was avoided; unequal thickness of the plates it was also important to avoid, in order to get rid of unequal strains from expansion, and if these disturbing causes could be removed, boilers would no doubt be much improved in durability. Firing below the boiler was he believed very objectionable in flued boilers, and should never be done where there was deposit from the water, since the deposit collected at the bottom just over the fire in the most injurious position; and it was an objection he considered to the plain cylindrical boiler that it required firing underneath. A lump of incrustation from the sides of the boiler dropping to the bottom in the night might cause a blister to be formed in the plate on the spot where it lay, by overheating from direct exposure to the fire without the contact of water to carry off the heat. He knew a great many 7 feet boilers with single and double internal fire-flues working at 100 lbs. per inch pressure, without any objection, and one of that kind was working at 150 lbs. pressure. In the case of multitubular boilers, unless they had the heat brought underneath the shell by a return flue they were exposed to an injurious strain from unequal expansion, on account of the shell remaining much colder than the tubes when it was simply cased with lagging and not heated by a return flue.

Mr. Goodfellow thought the extent of springing of the end plates in the construction of boiler he had proposed was so little as not to cause any damage to the material; if the plate were too much strained the iron would no doubt become damaged, but within that limit it did not receive any injury by alternate springing.

Mr. E. A. Cowper had found the two-flued boilers entirely satisfactory, both in durability and evaporative power, and had had them working for many years without giving any trouble from leakage or other causes; but to ensure this result they required wide water spaces, say 7 inches between the flues and 5 inches at the sides, or at the least 5 inches and 4 inches for small boilers. He was satisfied that with such allowance of water spaces an ample circulation would always be regularly kept up, and there would be no occasion for artificial means for maintaining a current; and there could never be more than a few degrees difference of temperature in the different parts of the boiler. Gusset stays he thought were good, and made durable and simple supports to the boiler ends; and with the front end angle iron put on outside the shell, and the joints of the fire-flues lapped in the direction of the draught, he believed the two-flued Cornish boiler would be found quite satisfactory and would work well for many years without leakage or undue straining of any portion.

The Chairman said he had two-flued boilers at his works that had been in constant use for 15 years, and no repairs had been wanted to them yet, and he had found them completely satisfactory; but then he never used angle iron in the construction of such boilers, considering there was not space enough for the plate to spring with the additional thickness of the angle iron. The plates of the shell and the flues were all flanged over at the ends for rivetting to the end plates, requiring of course best material for the plates; the water spaces he made never less than 6 inches, and preferred 8 inches: this construction gave great flexibility to the ends of the boiler, and there was no danger of failure he believed until the boiler was actually worn out with age.

He moved a vote of thanks to Mr. Goodfellow for his paper, which was passed.

The following Paper was then read:—

ON INCREASED BREAK POWER FOR STOPPING RAILWAY TRAINS.

By Mr. ALEXANDER ALLAN, of Perth.

The subject of increased Break Power for stopping quick trains in a shorter distance than is at present practicable has become of great importance, and the attention of railway companies has recently been specially drawn to it by the railway department of the Board of Trade, by whom a number of experiments were tried on breaks of engines and carriages; and a recommendation was made to the railway companies for carrying out a system of continuous breaks to the whole train. The subject was also under the consideration of a committee of the House of Commons last year, before whom evidence was given on the causes of railway accidents: this evidence was in favour of increased break power on the engine, if not too suddenly applied; for it was shown that no break on the carriages could be applied quickly enough to prevent accidents.

The subject of this paper is a plan for obtaining increased break power, by retarding the speed of the engine by means of a throttle valve placed in the exhaust pipe, which can be instantly closed to any required extent so as to obstruct the exit of the steam from the cylinders, the regulator remaining open; at the same time the exhaust steam is admitted to a small cylinder, the piston of which acts through levers upon a break on the engine wheels.

This arrangement is shown in Plate 45. Fig. 1 is a side elevation of a passenger engine, showing the steam break applied to the leading and trailing wheels simultaneously; Fig. 2 is an enlarged view showing the steam break cylinder A and the throttle valve B in the exhaust pipe, and Fig. 3 shows the position of the throttle valve in the expanded portion of the pipe. The spindle of the throttle valve B projects through the side of the smokebox, and is worked

from the foot plate by means of a lever and connecting rod C. The break cylinder A is 8 to 10 inches diameter; the exhaust steam is admitted into the bottom of the cylinder through a 1¼ inch pipe provided with a cock D, and acting on the underside of the piston lifts the break lever E and presses the break blocks F against the wheels. The cock D in the 1¼ inch pipe is worked from the foot plate by means of a lever H turning loose on the spindle of the throttle valve B; the throttle valve can thus be closed without at the same time admitting the exhaust steam to the break cylinder, while the latter can also be instantly applied in cases of sudden emergency. When the steam pressure is removed from the cylinder A, the weight of the piston and lever draws the break blocks back clear of the wheels; the break cylinder being contiguous to the smokebox, and the pipe leading to it short and open to the heat in the exhaust pipe, there is no risk of water accumulating in the cylinder to prevent the descent of the piston when the steam pressure is removed. The break blocks being under the charge of the engineman and fireman will be regularly adjusted by them.

The break cylinder applies the breaks simultaneously to the leading and trailing wheels of the engine, as shown in Fig. 1, and the driving wheels are at the same time retarded by the back pressure of the exhaust steam on the pistons consequent upon the closing of the throttle valve in the exhaust pipe; the pressure of steam in the break cylinder is the same as the back pressure in the driving cylinders, both being regulated by the extent of closing of the throttle valve. The power of the break cylinder is limited so as not to skid any of the wheels, in order to avoid wearing flat places on the tyres, and to produce the greatest effect in retarding the speed; a break power of from 14 to 22 tons can thus be obtained by the steam break alone. The break power obtained by the use of the throttle valve alone, retarding the driving wheels of the engine, is equal to that of the tender break, the regulator being open to the driving cylinders all the time. The application of the steam break by the engineman may be followed immediately by that of the tender break by the fireman, and the guard's break in the van next to the tender; thus giving at once a greater break power than has

usually been applied in retarding trains, and diminishing the liability to accidents from want of sufficient break power.

For the ordinary stoppages the throttle valve can be used to bring the train nearly to a stand, the tender break being applied for the last few yards only; this will effect a great saving in the permanent way, tender tyres, and break blocks. By partially closing the throttle valve, trains may be controlled to any desired speed in passing down an incline, while a great surplus of break power is reserved in the steam break cylinder and the tender and van breaks, to bring the train to a stand quickly on the incline: in an experiment made with a gross load of 200 to 210 tons, down an average incline of 1 in 80, of 5 miles length, the train was controlled by the throttle valve alone from a speed of 30 miles per hour at starting to 15 miles per hour down the whole incline. In approaching stations, half the time may be saved by the joint use of the tender break and the throttle valve alone in the exhaust pipe, and a still further saving of time effected by also admitting the steam to the break cylinder. By using the steam break for ordinary purposes in place of the tender break there is less risk of heating and flattening the tyres, since the steam break is arranged so as not to skid the wheels.

In this method of obtaining break power from the engine, the speedy reversing of the engine valve gear from forward to backward gear is rendered an easy operation, whereby a further increase of retarding power is obtained; for the exhaust steam at the back of the driving pistons being compressed in the exhaust port by the closing of the throttle valve, the pressure of steam inside the slide valves becomes equal to or greater than that outside in the steam chest, so that a balance of pressure is established, enabling the valves to be reversed instantly with perfect ease. The partial closing of the throttle valve may be employed to prevent violent slipping of the driving wheels, which will revolve only in proportion to the quantity of steam allowed to escape from the exhaust pipe, and this may be regulated to any extent by the throttle valve, which can be worked with greater ease and nicety than the regulator.

The retarding power of this steam break has been tested by the writer in some experiments made in August on the Scottish Central Railway, the results of which are given in the following Tables I, II, and III. In the two first trials, only the throttle valve in the exhaust pipe was used, without the addition of the steam break cylinder, thus retarding only the driving wheels of the engine by the back pressure of the exhaust: the third trial was made with an engine having the steam break cylinder in addition to the throttle valve.

Table I gives the average results of experiments made with a passenger engine, run over a level portion of the line, with pretty calm weather and rails dry; the engine weighed 18 tons and the tender 12 tons, making 30 tons total load; the break power was applied over the same ground in each case. The third result is an average of four experiments, the others of two each.

Table II shows the results obtained with a goods engine having four wheels coupled of 5 feet diameter; the engine weighed 26 tons and the tender 14 tons, and there were 18 wagons weighing 140 tons, making 180 tons total load. The break power was applied at the same mile post in each case, and over the same rails; the first ¼ mile from the post was level, and the next ¼ mile beyond was a rising gradient of 1 in 500; the weather was calm and the rails dry. The second result is an average of three experiments.

Table III gives the results of experiments made with a passenger engine having a steam break cylinder in addition to the throttle valve, under the same circumstances and over the same ground as in Table II; the engine weighed 18 tons and the tender 12 tons, and there were 11 empty carriages weighing 55 tons, making 85 tons total load. The carriage breaks were not applied in any case.

It appears therefore from these experiments that the retarding power produced by closing the throttle valve in the exhaust pipe is fully equal to that of the tender break, and the engine steam break also produces an effect fully equal to the tender break: so that by employing both throttle valve and steam break in conjunction with the tender break, the retarding power obtained is more than double that of the ordinary tender break alone.

TABLE I.

Passenger engine with Throttle Valve only.
Total load 30 *tons.*

Speed in running.	Break Power applied.	Time in stopping.	Distance run in stopping.
Miles per hour.		Seconds.	Yards.
26	Tender break only: steam shut off.	50	440
30	Throttle valve only: steam kept on.	52	440
30	Throttle valve and tender break: steam kept on.	21	200
36	Throttle valve and tender break, and engine reversed.	16	200

TABLE II.

Goods engine with Throttle Valve only.
Total load 180 *tons.*

Speed in running.	Break Power applied.	Time in stopping.	Distance run in stopping.
Miles per hour.		Seconds.	Yards.
30	No breaks applied: steam shut off.	130	1000
29	Throttle valve only: steam kept on.*	70	620
30	Tender break only: steam shut off.	65	610
30	Throttle valve closed and engine reversed.	58	440
30	Throttle valve and tender break, and engine reversed.	50	355

* Train not brought quite to a dead stand, owing to slight leak at throttle valve.

TABLE III.

Passenger engine with Throttle Valve and Steam Break.

Total load 85 *tons.*

Speed in running.	Break Power applied.	Time in stopping.	Distance run in stopping.
Miles per hour.		Seconds.	Yards.
36	No breaks applied: steam shut off.	156	1432
36	Throttle valve only: steam kept on.*	80	800
36	Tender break only: steam shut off.	66	715
36½	Throttle valve closed and engine reversed.	63	710
36	Throttle valve and tender break, and engine reversed.	50	460
36	Throttle valve and tender break: steam kept on.	55	450
36	Throttle valve and engine steam break: steam kept on.	50	400
36	Throttle valve, engine steam break, and tender break: steam kept on.	30	275
36	Throttle valve, engine steam break, tender break, and engine reversed.	23	220

* Train not brought quite to a dead stand, owing to slight leak at throttle valve; but speed very slow for the last 220 yards.

Mr. ALLAN observed that the importance of an increased power for stopping railway trains in cases of emergency, proportionate to the increase that had taken place in the speed and weight of the trains, had long been felt; and he was satisfied that to accomplish this effectually it was essential to arrange for the break power to be applied

by the engine driver, as there was no time for communication with the guard, and the mischief was done before the guard could get his breaks applied. The great object to be attained was the application of a powerful retarding force at the earliest possible moment to check the speed of the train, and the value of the break mainly depended upon its instantaneous action as soon as the danger was perceived; and as the weight of the engine and tender formed a large portion of the total weight of the train, and the steam break was under the immediate control of the engine driver, it afforded the most efficient means of accomplishing this object. By the experiments it was found that closing the throttle valve so as to shut the escape from the engine cylinders, which was done instantaneously, produced a retarding effect as great as that of the tender break; and the addition of the steam break caused the train to be stopped in less than half the distance. The throttle valve also enabled the engine to be reversed easily, by balancing the pressure on the slide valves, removing the ordinary difficulty in reversing large engines.

Mr. R. Morrison had seen some experiments upon a steep incline of 1 in 40 on the Edinburgh and Glasgow Railway, with a steam break contrived by Mr. Paton which gave a very powerful retarding force; the break was applied to the leading and trailing wheels of a large tank engine having all the wheels coupled, and the pressure was produced by a steam cylinder communicating direct with the boiler. The action of the break was very efficient, but he believed the principal objection to it was found to be the great shock caused by its sudden application, which often deranged the levers of the apparatus and occasioned an objectionable concussion to the train.

Mr. Allan said that with the plan of the throttle valve in the exhaust pipe this objection was removed, as the pressure came on gradually by the gradual compression of the exhaust steam; and no objectionable shock was perceived beyond what was of course unavoidable in stopping a quick-moving train within a short distance: a train at a speed of 40 miles per hour was stopped in 150 yards upon a level by means of the steam break and tender break without any objectionable shock being produced. The throttle valve and steam break were found to answer well in going down inclines, where

the tender break was ordinarily used, and were more convenient for application, and had the advantage of saving the wear of the tender wheel tyres which were generally skidded by the breaks; but the pressure on the engine breaks was adjusted by the size of the steam cylinder so as not to be able to skid the wheels.

The CHAIRMAN observed that it was certainly an important subject, and it had become very desirable to have an increased power for stopping trains which would be promptly available for application. He proposed a vote of thanks to Mr. Allan for his paper which was passed.

The following Paper was then read :—

DESCRIPTION OF A STEAM CRANE.

By Mr. J. CAMPBELL EVANS, of Greenwich.

The Steam Crane described in the present paper was designed more especially for use on board steam vessels; and the chief points to be aimed at were consequently compactness, facility of fixing, simplicity in the mode of working, and durability. In cranes usually constructed, the boiler being separate from the engine, the union joints of the steam pipe are very liable to leak; and the writer believes there are very few such cranes where this circumstance has not been a continual source of trouble and annoyance after a few months' regular work. Frequently the boiler is a considerable distance away from the cylinder, and then the steam and feed pipes are liable to be injured in stowing the cargo; in addition to which, the condensed steam strains the machinery and keeps the deck of the vessel constantly wet and dirty.

To obviate these disadvantages, in the present steam crane, shown in Figs. 1, 2, and 3, Plates 46 and 47, the boiler A is placed as close as possible to the crane, and revolves with it; and by making the top of the boiler of cast iron with lugs for attaching the tension rods, it serves the double purpose of boiler and crane post. The bed plate B upon which the crane and boiler are placed is fixed to the foundation plate C by a centre bolt, which bears all the upward strain; the downward pressure is taken by the rollers D running on the foundation plate C; this plate is solidly bedded on timber laid on the deck of the vessel, which thus requires very little alteration.

To avoid upright tubes and horizontal tube plates, the heating surface of the boiler A is arranged in cones, as shown in the vertical section, Fig. 4, Plate 47; the first cone or firebox is

exposed to the direct radiation of the fire, after which the heat passes through the opening E nearly opposite the firedoor into the space between the second and third cones, where it is absorbed by the water spaces on either side, and passes round to the funnel F opposite. In this way a sufficient heating surface is obtained without any horizontal surfaces in the boiler for deposit to accumulate upon. The two angles or bottoms of the water spaces are below the direct action of the fire, and are connected by pipes G to allow for the circulation of the water, provided with plugs and cocks for cleaning. The water tank H is placed under the boiler, this position serving to heat the feed water and to preserve the cast iron bed plate B from danger of fracture by the heat of the fire.

The crane is worked by a single oscillating cylinder I, shown enlarged in Fig. 8, Plate 47, supported by brackets on the bed plate B. The joints for the steam and exhaust pipes at the trunnions are made tight by gun metal cones J, Fig. 7, fitted to the trunnions and held by studs in the brackets; when these have become polished by working, the wear upon them is very slight, and this construction has been found very suitable for the rough treatment to which cranes are usually subject. On the crank shaft K is a friction wheel L, Figs. 1 and 2, Plate 46, grooved according to Mr. Robertson's plan and kept continually revolving by the engine. On the second shaft M is another friction wheel N, which can be moved by the lever O into gear with the driving wheel L, or by an opposite motion of the lever can be pressed against the break P, or when lowering can be held between the two. The other end of the shaft M carries pinions gearing into wheels on the shaft of the chain barrel Q. There are two pair of wheels and pinions R and S, for varying the speed according to the weight to be raised: the pinions are thrown in and out of gear by a sliding key, shown enlarged in Fig. 6, instead of the ordinary clutch; by this means the width between the frames that would be required for moving the ordinary clutch is saved.

The writer believes the principal difficulty experienced in steam cranes for ship purposes is in the arrangement of the turning gear; so that when the vessel leans over to one side, the crane shall be powerful enough to swing the weight and yet not cause a sudden start

or shock to break the gear. In this crane a coned friction clutch is used, shown enlarged in Fig. 5, to allow a slip at first and to start the weight gradually; and the arrangement of the foundation plate C of the crane admits of a much larger spur wheel than usual being employed to bring up the power. On the crank shaft K is a worm T working into a worm wheel on the shaft of the bevil wheel U, Figs. 2 and 5, which gears into the two bevil wheels above and below; as these are kept constantly revolving by the engine, the crane can be moved round either way by raising or lowering the coned clutch V by the lever and screw W. The lifting lever O and the screw W being close together, as seen in Fig. 3, the two operations of lifting and turning the weight are easily managed by one man.

The valve motion of the oscillating cylinder I, Fig. 8, is designed to compensate for the oscillation of the cylinder without the use of sweeps and guides. A radius rod X is centred on the cylinder bracket and connected to the eccentric rod Y by a link Z, to which the valve rod is attached by a pin. The link Z combines the vibrations of the eccentric rod Y and radius rod X, so that at the point where the valve rod is attached the curve described by the radius rod compensates for that described by the eccentric rod in such a degree as to bring the valve rod into the curve it would naturally be made to describe by the oscillation of the cylinder, as shown by the diagram, Fig. 9.

Mr. Evans observed that the crane was intended as a machine of simple construction complete in itself, including boiler, for fixing in such situations as on decks of vessels or on quays, where generally the expense of larger stationary boilers for working a number of separate steam cranes could not be gone to. These cranes had worked very satisfactorily, the only wear after more than a year's work being in the bearing of the crank shaft, and by tightening up the nuts of the cap 1-8th of a turn, all the wear of some months was taken up. There was an advantage in the leverage in turning round, and the crane was found very convenient for handling; the grooved friction

wheels for connecting and disconnecting the motions had proved very satisfactory, and worked smoothly and efficiently.

Mr. H. Maudslay enquired what pressure of steam was used, and what weight could be easily lifted by the crane; and what was the cost of the whole.

Mr. Evans replied that 30 to 40 lbs. steam was used, and the crane shown in the drawings, the largest size yet at work, lifted 50 cwts.; but a larger size was being constructed to lift 50 cwts. 42 feet high in half a minute. The cost of the cranes at present made was about £200 complete, and the cost was very moderate from the simplicity of construction of the whole—crane, engine, and boiler being combined in one machine: no pipes were required for connexion to the boiler as in detached steam cranes, and no fixings were wanted for the crane or boiler: all that was required was to lay down 4 inch timbers to bed the frame upon, and it was a particular advantage in the case of ships that no holes were required in the deck for the crane post, the whole being self-contained.

Mr. E. A. Cowper thought it was a disadvantage in the arrangement that the steam must be shut off directly the load was off, to prevent the engine running away; and a single cylinder had this disadvantage, that it might stop on the centre, causing a delay in starting the crane again. He thought that for working a crane it was preferable to have two cylinders working cranks at right angles and with link motion, as in Taylor's steam winch; the engines were then started or reversed readily, in whatever position they might have been stopped, and there was a decided advantage in thus getting rid of the flywheel.

Mr. Evans replied this difficulty of a single cylinder was completely met in the present crane by having a small hole remaining open when the steam was shut off, which allowed steam still to pass just sufficient to keep the engine constantly moving at a slow speed and turning only the first of the friction wheels. A double-cylinder crane would involve greater cost and complication, and a good deal of knocking was liable to occur in the gearing of a quick-working crane on that plan; there was also the objection of water accumulating in the cylinders when standing, which was avoided by having the engine always moving.

Mr. H. Maudslay observed that the boiler appeared of peculiar construction, and asked how it was found to work and how long it took to raise steam.

Mr. Evans replied that the boilers were working very satisfactorily and there had not been any difficulty experienced with them; the steam was got up to 30 lbs. pressure in from 30 to 40 minutes from cold water: there were 14 of the boilers at work with the cranes.

The Chairman observed that there was now a great demand for machines of that kind, to facilitate work and take the place of hand labour; this was an ingenious arrangement for the purpose, and formed a compact and economical steam crane, though he should be inclined to prefer a double-cylinder engine, particularly for lowering, as in lowering weights by the engine it would be apt to go by jerks with a single cylinder. On the Great Eastern a small engine with a pair of oscillating cylinders was fixed on the deck, with a detached boiler, working four drums by means of friction wheels and taking the chains from four crane jibs, two on each side of the vessel, which could be all worked independently, the engine being kept constantly running.

Mr. Evans said he found that with the friction wheels the difficulty in working with a single cylinder was quite removed, and the crane could be readily held still or worked at any speed either in raising or lowering; the objection of irregularity in motion generally entertained against single cylinders did not apply to a small cylinder running fast, which gave a very steady motion, and the cranes had been found entirely satisfactory in working by those who had employed them. The crane post being formed by the boiler made a compact and convenient arrangement, since the boiler served as a counterpoise; and it made a steady crane without requiring fixing.

Mr. H. Maudslay thought it a good idea to put the boiler at the back end to balance the jib, which made an advantageous arrangement. In a 30 ton steam crane recently erected in the wharf at Messrs. Maudslay Son and Field's works, the engine was fixed upon the jib, consisting of a pair of small cylinders with short stroke working cranks at right angles: the crane lifted 30 tons, and the lowering and raising were done very smoothly by the cylinders; for lowering such a weight double cylinders were of course wanted to prevent a jerk.

The CHAIRMAN moved a vote of thanks to Mr. Evans for his paper, which was passed.

A description was then read, communicated through the Secretary, of the Pumping Engines at the Arthington Water Works for the water supply of Leeds.

The Meeting then terminated, and after the meeting the Members proceeded by special train to visit the Arthington Water Works Engines.

In the evening a large party of the Members and their friends dined together at the Wellington Hall.

On the following day an excursion of the Members took place to the Low Moor Iron Works, and the Works of Messrs. Titus Salt and Co., Saltaire.

PROCEEDINGS.

November 2, 1859.

The General Meeting of the Members was held at the house of the Institution, Newhall Street, Birmingham, on Wednesday, 2nd November, 1859; Henry Maudslay, Esq., Vice-President, in the Chair.

The Minutes of the last General Meeting, held in Leeds, were read and confirmed.

The Chairman alluded to the irreparable loss that had been sustained by the profession and the world at large, since their last meeting, in the recent lamented death of their ex-president, Mr. Robert Stephenson; and he thought they could not commence the business of the present meeting without an expression of their deep regret at this mournful event, and their high appreciation of the great mechanical genius and many noble qualities of the deceased. Mr. Robert Stephenson had taken a strong interest in the development of the Institution from its commencement, having succeeded in the presidency his father, the late Mr. George Stephenson, their first president; and both had largely aided in promoting its welfare by their counsel and assistance, each of them presenting a donation of £100, and Mr. Robert Stephenson having become a life member of the Institution. He was most highly and universally esteemed, both from his wide professional reputation and on account of his liberal and unostentatious philanthropy, which doubly endeared him to all who had the privilege of being numbered amongst his friends. In disposing of the great wealth accruing to him from his lofty position and from many years of active

and honourable professional engagements, all knew how liberal were the donations and bequests made by him during his lifetime and at his decease for the advancement of professional and scientific pursuits, for the improvement of practical men, and for the promotion of charitable and benevolent objects; amongst which might be mentioned his handsome donations to the Newcastle Philosophical Institution and Infirmary. All who witnessed the funeral in Westminster Abbey, and the vast concourse assembled on that occasion out of sincere regard and respect for his memory, would be convinced how widely the feeling was entertained that England had lost a most estimable man, and one who could not easily be replaced: the strong interest that was taken in the ceremony was shown by the large attendance of civil and mechanical engineers from all parts of the kingdom, and the great feeling manifested by all present. The removal by death of such a man was an event that could not be allowed to pass without an expression of their feeling of deep regret and their lasting remembrance of the connexion with Mr. Robert Stephenson which it had been their happiness to enjoy as members of the Institution.

The Chairman announced that the President, Vice-Presidents, and five members of the Council in rotation, would go out of office in the ensuing year, according to the rules of the Institution; and that at the present meeting the Council and Officers were to be nominated for the election at the Annual Meeting.

The following list of Members was adopted by the meeting for the election at the Annual Meeting:—

PRESIDENT.

James Kennedy, . . . Liverpool.

VICE-PRESIDENTS.

(*Six of the number to be elected.*)

Sir William G. Armstrong, . Newcastle-on-Tyne.
Samuel H. Blackwell, . Dudley.
Alexander B. Cochrane, . Dudley.
James Fenton, . . . Low Moor.
Benjamin Fothergill, . . Manchester.
James Kitson, . . . Leeds.

Henry Maudslay, . . .	London.
John Penn, ...	London.
Robert B. Preston, . .	Liverpool.
John Ramsbottom, . .	Crewe.
Joseph Whitworth, . .	Manchester.
Nicholas Wood, . . .	Hetton.

COUNCIL.

(*Five of the number to be elected.*)

John E. Clift, . . .	Birmingham.
Edward A. Cowper, . .	London.
William G. Craig, . . .	London.
John Fernie, . . .	Derby.
George Harrison, . . .	Birkenhead.
Sampson Lloyd, . . .	Wednesbury.
Charles May, ...	London.
J. Scott Russell, . .	London.
C. William Siemens, . .	London.
Edward Wilson, . . .	Worcester.

The Chairman announced that the Ballot Lists had been opened by the Committee appointed for that purpose, and the following New Members were duly elected:—

MEMBERS.

William Adams, . . .	London.
Robert Beacock, . . .	Leeds.
Thomas Egleston, Jun., . .	Paris.
Robert Fogg, . . .	London.
Henry William Harman, .	Manchester.
Jeremiah Head, . . .	Leeds.
Matthew Murray Jackson, .	Zurich.
John McKenzie, . . .	Worcester.
Jean François Paquin, . .	Madrid.
Jonathan Pim, . . .	Limerick.

John Platt, ...	Oldham.
William Richardson, . .	Oldham.
John Robinson, . . .	Manchester.
Charles Sacre, . . .	Manchester.
Joseph Shuttleworth, . .	Lincoln.
Charles P. Stewart, . .	Manchester.
Henry Wickham Wickham, M.P.,	Low Moor.
Lamplugh Wickham Wickham,	Low Moor.
Thomas Bradbury Winter, .	London.
Joseph Wright, Jun., . .	Birmingham.

HONORARY MEMBER.

Alexander Clunes Sherriff, .	Worcester.

The following Paper was then read :—

DESCRIPTION OF OATES' BRICK-MAKING MACHINE.

By Mr. JOHN E. CLIFT, of Birmingham.

In ordinary hand-made bricks, the main expense of the process of making, besides the burning, consists in the preparation of the clay, so as to render it sufficiently ductile to allow of its being forced into the moulds by hand-pressure; this necessitates the mixture of water with it, and thus requires also the further process of drying the bricks before placing them in the kiln. The risk of damage and the delay from weather also add materially to the expense of hand-made bricks. The application of machinery to the manufacture of bricks has for its objects economy, certainty, and expedition of production, and improvement in the quality and appearance of the bricks. It is still a question how far these objects have been attained; and out of the large number of machines invented for brick-making but few are at present in regular work: omitting tile and pipe-making machines. The machines now at work may be divided into two classes:—those which operate upon the clay in a moist and plastic state; and those for which the material requires to be dried and ground previous to being moulded. In the former class, the plastic column of clay, having been formed in a continuous length by the operation of a screw, pugging blades, or rollers, is divided into bricks by means of wires moved across, either whilst the clay is at rest, or whilst in motion by the wires being moved obliquely at an angle to compensate for the speed at which the clay travels. In consequence of the clay having to be made sufficiently soft to allow of this wire-cutting, the bricks made are but little harder than those made by hand, and require similar drying before being placed in the kiln; and this drying, together with the expense of preparing the clay in the requisite manner, renders the expenses of manufacture

similar to those involved in hand-made bricks. In the second class of machines, a superior finish of appearance is obtained in the bricks by their compression in a dry state in the mould; and the objection of subsequent drying is avoided: but the additional preparation requisite in drying the clay and reducing it to a sufficiently fine and uniformly pulverised state, and the more expensive character of the machinery involved, add materially to the cost of manufacture.

By means of the brick-making machine described in the present paper, which is the invention of Mr. Oates of Erdington near Birmingham, the difficulty of previous preparation of the clay required in the second class of machines is not incurred; while at the same time the subsequent drying of the bricks required with the other machines is avoided. In this machine the clay is used of such a degree of dryness as to allow of its being mixed up and macerated and compressed into bricks by a single continuous action; the clay being formed into a continuous column and compressed into the moulds by the action of a revolving vertical screw. The clay requires generally no previous preparation beyond that given by the ordinary crushing rollers, and is sometimes ready for putting into the machine direct from the pit; in other cases, where containing a mixture of stones, it is first passed through a pair of crushing rollers.

The machine is shown in Plates 48 to 51. Fig. 1, Plate 48, is an end elevation of the machine; Fig. 2, Plate 49, is a front elevation, and Fig. 3 a plan; Fig. 4, Plate 50, is a vertical transverse section enlarged, and Fig. 5 a plan of the screw; and Fig. 6, Plate 51, is a longitudinal section of the machine.

The cast iron clay cylinder A, Fig. 4, Plate 50, is expanded at the upper part to form a hopper into which the clay is supplied, and the lower cylindrical portion is about the same in diameter as the length of the brick mould F at the bottom of the pressing chamber B. The vertical screw C is placed in the axis of the clay cylinder, and carried by two bearings in the upper frame D: this screw is parallel at the lower part, the blade nearly filling the parallel portion of the clay cylinder, and is tapered conically at the upper part to nearly double the diameter. When the clay is thrown loosely into the

hopper, it is divided and directed towards the centre by the curved arm E revolving with the screw shaft, and drawn down by the tapered portion of the screw into the parallel part of the clay cylinder, in sufficient quantity to keep this part of the cylinder constantly charged, any surplus clay easily escaping laterally into the loose clay in the hopper. The clay is then forced downwards by the parallel portion of the screw into the pressing chamber B, and into the brick mould F, which consists of a parallel block equal in thickness to a brick and sliding between fixed plates above and below, and containing two moulds F and G, Fig. 6, Plate 51, corresponding in length and breadth to the bricks to be made.

The mould block F, Fig. 6, Plate 51, is made to slide with a reciprocating motion by means of the revolving cam H, which acts upon two rollers in the frame I connected to the mould block by a rod sliding through fixed eyes; and the two brick moulds are thus placed alternately under the opening of the pressing chamber B to receive a charge of clay, the mould block remaining stationary in each position during one quarter of a revolution of the cam H. When the brick mould F is withdrawn from under the press chamber, the brick is discharged from the mould by the descent of the piston K, which is of the same dimensions as the brick mould; the piston is pressed down by the lever M worked by the cam N, when the brick mould stops at the end of its stroke, and is drawn up again before the return motion of the mould begins. A second piston L acts in the same manner upon the second brick mould G; and the discharged bricks are received upon endless bands O, Figs. 1, 2, and 3, Plates 48 and 49, by which they are brought successively to the front of the machine, where they are removed by boys to the barrows for conveying them to the kiln to be burned.

The solid block that divides the two brick moulds F and G is slightly wider than the discharge opening at the bottom of the pressing chamber B, having an overlap so that the making of one brick is terminated before that of the next begins, in order to ensure completeness in the moulding. During the instant when this blank is passing the opening at the bottom of the pressing chamber, the

discharge of the clay is stopped, and it becomes necessary to provide some means of either relieving the pressure during that period or stopping the motion of the pressing screw. The latter plan would be impracticable; and in this machine the former mode is provided by a very ingenious contrivance, forming in effect a safety valve, which prevents the pressure in the chamber from increasing when the brick mould is shut off, and also serves to maintain a uniform pressure during the formation of the brick, so as to ensure each mould being thoroughly and equally filled with clay. This is effected by an escape pipe P, Fig. 4, Plate 50, which is similar in form to the brick mould, but extends horizontally from the side of the pressing chamber, and is open at the outer extremity. The regular action of the screw forces the clay into this escape pipe as far as its outer extremity, forming a parallel bar of clay in the pipe: the resistance caused by the friction of this bar in sliding through the pipe is then the measure of the amount of pressure in the machine; and this pressure cannot be exceeded in the machine, for the instant that the brick mould is full the further supply of clay fed into the pressing chamber by the continuous motion of the screw escapes laterally by pushing outwards the column of clay in the escape pipe. The uniform pressure of every brick in the mould up to this fixed limit is ensured by the escape pipe not beginning to act until that limit of pressure is reached. Its action is similar to that of a safety valve; and the amount of pressure under which the bricks are made is directly regulated by adjusting the length of the escape pipe.

The important result of this arrangement is that it prevents any risk of overstraining the machine; and the action of the screw has a special advantage in filling the brick mould with a continuous uniform stream of clay, which is being constantly supplied at a uniform moderate pressure, so as to ensure the mould being thoroughly filled with a uniform density of clay throughout, without requiring any sudden excessive pressure that would cause the brick to be denser on the outside than in the centre. The pressing chamber is made larger in transverse area than the supplying screw cylinder, in order to increase the uniformity of pressure on the clay in the chamber; and the regularity of action is shown by the working of the escape pipe,

which discharges a continuous bar of solid clay, advancing by intermittent steps of $\frac{1}{4}$ to $\frac{1}{8}$ inch length each time that the brick mould is shut off and changed. The projecting piece of clay from the end of the escape pipe is broken off from time to time and thrown back into the hopper of the machine.

The upper side of the solid block separating the two moulds F and G is faced with steel, as shown in Figs. 4 and 6, Plates 50 and 51, and the upper face of the brick is smoothed by being sheared off by the edge of the opening in the pressing chamber; the under face of the brick is smoothed by being planed by a steel bar R, Fig. 6, fixed along the edge of the under plate, having a groove in it for discharging the shaving of clay taken off the brick.

The screw shaft is driven by bevil gear from the shaft S, Fig. 1, Plate 48, which is driven by a strap from the engine, the speed being adjusted according to the quality of the clay or the wear of the screw. The screw is driven at about 30 revolutions per minute, delivering the bricks at the rate of about 30 per minute when at full speed, or one brick for each revolution of the screw. The machine completes regularly in ordinary work 12,000 bricks per day, or an average of 20 good bricks per minute. The amount of power required for driving the machine and the wear of the screw vary according to the material worked. At the Oldbury Brick Works, where two of the machines have been working regularly for three years, the clay is a calcareous marl, and the power required for each machine is about 12 horse power; the rate of manufacture is 20 bricks per minute.

The wear of the screw varies considerably according to the material of which it is made and the quality of the clay worked in the machine. In a machine working at Cobham cast iron screws have been worn out in a short time with very silicious material; but in two machines working at Gosport for two years, the screws have been renewed only once in that time, although as much as 3 million bricks were made by the machines. In another machine working for two years at the Blaenavon Iron Works, the screw and mould block have been made of gun metal, and are found considerably more durable.

With regard to the burning of the bricks made by these machines, no difficulty has been found from the bricks not having been dried before stacking in the kiln ; and a very small proportion of waste is made in the burning. Where the clay contains much alumina and retains more moisture in consequence, it is found advisable to stack the bricks in the kiln in "lifts" as they are termed, of from 15 to 20 courses each ; as soon as the bottom lift has been stacked, small fires are lighted to drive off the steam from the bricks which might otherwise soften those stacked above ; the middle lift is then stacked and similarly dried, and then the top lift, after which the full fires are lighted. In other cases the whole kiln is stacked at once, and no difficulty is experienced from the lower bricks not being able to bear the weight of the rest.

The quality of the bricks is shown by the specimens exhibited from machines working in different places ; and they have been found thoroughly satisfactory in soundness and strength. The crushing strength of these bricks made in the machines at Oldbury has been found to be double that of the hand-made blue bricks of the neighbourhood, being an average of 150 tons as compared with 76 tons, or 8024 lbs. per square inch compared with 4203 lbs. The transverse strength with 7 inches length between the bearings is

			Excess over hand-made.
Hand-made bricks	2260 and 2440,	average 2350 lbs.	
Machine-made bricks...	2960 and 3210,	,, 3085 ,,	31 per cent.
Do. hard burned	3960 and 4680,	,, 4320 ,,	84 per cent.

With regard to the economy of manufacture by the machine, the two expensive processes of drying the bricks before burning as in hand-making and wet machine-making, or of preparing and pulverising the clay as in dry-clay machines, are dispensed with entirely or to a great extent ; and the power required for working and the cost of repairs are much reduced as compared with other machines by the simplicity of construction : the mode of applying the power by the action of the screw with the provision of the escape pipe effectually prevents any undue strain upon the machine, and avoids the sources of wear arising from very heavy pressure or the concussion of blows. The economy and advantages resulting from the application of machinery to the manufacture of bricks are so important that

when once the practical difficulties are thoroughly surmounted it must be expected to have a rapid extension; and instead of so small a proportion being manufactured by machinery out of nearly 2000 millions of bricks made annually in this country, the time cannot be far distant when hand-made bricks will become nearly as rare as flail-thrashed corn.

Mr. Clift said he had seen the working of the machines at Oldbury on several occasions, and they worked exceedingly well, producing bricks of a uniform good quality with great rapidity. In some others of the machines it had been stated that as many as 30 bricks per minute had been made, and even 20,000 bricks per day had been produced by one machine when working under very favourable circumstances; but in the machines that he had seen the regular run of work that was produced with certainty was 20 good bricks per minute exclusive of wasters, or 12,000 per day of 10 hours, with a 12 horse power engine; and the machine could be relied on to continue turning out this quantity of bricks throughout the entire year. He exhibited a number of samples of the bricks made by the machine, which he considered were fair specimens of the ordinary quality produced and fit for any kind of work; and showed also specimens made from different qualities of clay in different parts of the country.

Mr. H. G. Longridge thought the machine described in the paper was decidedly the most perfect brick-making machine he had yet seen: he had seen it at work at Oldbury and at Stourbridge, and the bricks produced appeared to be of very good quality. At Oldbury there was a great quantity of stone in the clay, forming a material which it would be almost impossible to work for hand-made bricks; and he was surprised at the excellence of the bricks that he saw turned out by the machine with that clay. The machine seemed well contrived for durability, and would be subjected to but a small amount of wear, the greater part of the wear and tear being on the screw; the amount of this wear was perhaps rather understated in the paper, as a

considerable amount of wear must generally be expected. As soon as the screw had become much worn a waste of power would occur, from the clay slipping back past the screw, and being merely kneaded up without being pressed into the mould; and there must always be a spare screw at hand to replace that in the machine as soon as worn out. In reference to the quantity of bricks produced by the machine, he saw them turned out as fast as the boys could pick them off from the front of the machine.

Mr. E. A. Cowper remarked that the bricks exhibited had not any hollow or frog in the upper face; and enquired whether that could be done by the machine, as it was generally considered an advantage for holding the mortar.

Mr. Oates said this had not yet been done, but an arrangement was now being made to accomplish it with the machine. Some of the bricks exhibited having a stamp on one of the faces had been pressed in a separate pressing machine immediately on leaving the moulding machine, and some model bricks were shown on which the stamp had been put in the moulding machine by an improvement in the apparatus.

Mr. J. Manning thought the machine that had been described was well worth the attention of practical men: he had seen three of the machines at work at Oldbury and Stourbridge, and was satisfied of their practical efficiency; in each case excellent bricks were turned out. The rate of production he observed to be frequently 30 bricks per minute, with some few wasters amongst this number; and he was sure therefore that 20 good bricks per minute was safely within the limit. An important object to be aimed at in the construction of brick-making machines was to reduce the number of processes through which the clay had to pass in being formed into bricks, in order to simplify the application of machinery and effect economy in cost and time of manufacture: this object he thought was well carried out in the machine now described, for the clay was taken direct from the pit, passed through the crushing rollers, and then fed straight into the moulding machine; and in a quarter of an hour after being brought from the pit he had seen the same clay in bricks stacked in the kiln; and in a few days they were burned ready for use.

Mr. Sampson Lloyd observed that defects had been found in previous brick-making machines, particularly in the quality of the bricks produced, and asked whether this was obviated in the present machine; it would be an important point gained if these difficulties in applying machinery to brick making could be successfully overcome.

Mr. Clift thought that much of the difficulty experienced in the use of other brick-making machines arose from the employment of dry clay for making the bricks, in which case the clay was required to be previously dried and prepared for the machine; while at the same time some doubt had been felt whether dry-clay bricks were not of too close a quality to allow of their being thoroughly vitrified in burning. In hand-made bricks and the bricks made by the machine now described, the clay was more open, not having been dried before moulding, and not having been subjected to a heavy pressure in moulding; and the moisture being dried out in burning, the heat could more easily get to every part of the bricks so as to burn them thoroughly.

Mr. C. May considered the defects of brick-making machines applied more particularly to dry-clay machines, in consequence of the greater complication of machinery required, and the greater difficulty of burning the bricks sound and strong, than with moist clay. He thought the machine now described was a very good one, simple and complete in its action; but doubted whether bricks could be moulded at so low a cost by machinery as by hand, since they were already made so cheaply by hand that there was not much margin for saving by the application of machinery. He also was not satisfied as to the safety of the conclusions drawn with regard to the number of bricks that could be regularly produced by the machine; for though 20 good bricks per minute might no doubt be made, it did not follow that [illegible]0 bricks per day could be made during an entire year; and the [illegible]sults of a year's regular work were required, in order to obtain a fair average. A variety of disturbing circumstances might be met with in the same brick field; the clay might be drier or containing a greater quantity of stones in one place than in another, which would make a considerable difference in the rate at which the bricks were turned out by the machine. The machine now described was certainly one of the best he had seen for working raw clay direct

from the pit: a more severe pressure might perhaps be employed with advantage, to obtain a superior finish in the bricks. The samples of bricks exhibited from the present machine he observed were many of them unusually heavy, which would be considered an objection in building.

Capt. Goold said he had seen a quantity of bricks made by one of these machines at Cobham, of the same size as the ordinary London bricks, for the purpose of being laid with them; the size of the bricks would be determined by the size of mould employed.

Mr. E. A. Cowper enquired what was the total cost of making bricks by the machine, taking the actual make of a long period, including the charge for the machine.

Capt. Goold replied that the cost of brick making varied much according to the price of coal in different localities; but there was very little variation in the price of the unburned bricks made by the machine, the difference arising mainly from the varying amount of royalty charged on the clay in the pit, which varied from 1*s.* to 2*s.* 6*d.* per 1000 bricks. With the machine at Cobham, which was employed by Messrs. Peto and Betts upon their works and coming under his constant observation, he considered that the total expenses exclusive of coals would not have exceeded £864 for a year of 261 working days, including all wages and interest on capital, had not the machine been at too great a distance from the clay pit, requiring four barrow men to keep it supplied with clay, which added considerably to the amount paid in wages. The machine had now been at work without intermission for six months, and the rate of production had reached 200,000 bricks in a fortnight of 11 days; the average number per week of 5½ days was considered to be about 80,000, or at the rate of 24 bricks per minute. The contract for the bricks in and out of the kilns, exclusive of the cost of the coals, was first taken at 5*s.* 9*d.* per 1000 bricks; which was afterwards increased to 6*s.* 9*d.*, owing to the distance of the clay from the machine. To this had to be added 6*d.* per 1000 royalty, and the wages of the engine driver at 6*d.* per 1000, raising the expenses to 7*s.* 9*d.* per 1000 bricks. The quantity of coals required for burning the bricks and for the engine driving the machine might safely be taken at ½ ton per 1000; and the price of coal there

being 25*s*. per ton, the total cost of making the bricks by the machine amounted to 20*s*. per 1000, including the burning. This was the actual result obtained with the machine at Cobham during six months' continuous working; and the rate of production having been as many as 200,000 bricks in 11 days, he was convinced that 20 bricks per minute could be fully depended upon as quite on the safe side.

Mr. W. May asked whether the cost of 20*s*. per 1000 included the interest upon the cost of the establishment and the engine for driving.

Capt. Goold replied that the interest on the entire outlay of capital and the whole of the expenses involved were reckoned in the cost of 20*s*. per 1000 bricks, including the 16 horse power portable engine for driving the machinery.

Mr. J. Manning had obtained the actual cost of labour in working some of the machines during a considerable period, having ascertained the cost of each process. In one instance the total cost of labour amounted to 5*s*. 6*d*. per 1000 bricks, including digging the clay, winding it up an incline from the pit, passing it through rollers, wheeling it to the machine, stacking the bricks in the kiln, and afterwards drawing them when burned; the rate of wages being about an average of those paid in the manufacturing districts. In another instance the total cost of labour amounted to 6*s*. per 1000 bricks, out of which 10*d*. per 1000 had to be paid for wheeling the clay from one part of the establishment to another, owing to bad arrangement of the premises; had the ground been properly laid out, this item might have been reduced to 4*d*. or 2*d*. per 1000, reducing the cost of labour to 5*s*. 6*d*. or 5*s*. 4*d*. Hence the cost of labour might be safely taken at from 5*s*. 6*d*. to 6*s*. per 1000 bricks; and the total cost per 1000 bricks would then be obtained in any instance by adding the royalty on the clay and on the machine, together with the cost of ½ ton of coals for burning the bricks and driving the machine. The greatest variation was in the cost of coal, which varied from 4*s*. per ton in the mineral districts to 18*s*. or 20*s*. per ton in the neighbourhood of London.

Mr. H. G. Longridge asked whether with the machine the clay had to be turned over and tempered by exposure for a winter, as for hand-making, or whether it could be used direct from the pit.

Mr. CLIFT said that in the Oldbury district the clay was not tempered, but simply passed through the crushing rollers and fed direct into the machine.

Capt. GOOLD stated that in the case of the machine at Cobham the works had been started only six months, so that there had been no time for tempering the clay for all the large quantity of bricks that had been made by the machine in that time, and the clay was fed direct into the machine without any delay for preparation. The material worked at Cobham, of which a specimen was shown, was very unfavourable for brick making, and great difficulty was experienced at first in stacking the bricks for burning, as the clay was so weak and friable that hand-made bricks made of it were crushed by the slightest pressure. The machine however had the advantage of enabling bricks to be made by it in districts where the material did not admit of their being made by hand; and from the trials already made with the machine in different localities he was satisfied that any description of brick earth, from the stiffest and most sticky London clay down to the driest sandy material, could be successfully worked by the machine. He exhibited a brick made for trial of an extreme quality of material, which contained 84 per cent. of pure silica held together only by a little white powder, and without any alumina in it.

Mr. C. MAY asked what the remaining 16 per cent. of the clay consisted of, as it was important to know the other constituents; for if the clay consisted of such pure silica, free from alumina, it would be an invaluable material for making firebricks.

Capt. GOOLD did not remember what were the other constituents of the clay, but had understood there was no alumina at all in it. The silicious brick was made in the machine at Oldbury, but the clay was from Tenby in South Wales.

Mr. W. HAWKES observed that an important quality to be considered in all bricks was the extent to which they absorbed water, since it was impossible to build dry houses with bricks that absorbed water readily. The absorption of ordinary bricks was about 1-9th of their weight, or a brick of 9 lbs. weight would absorb about 1 lb. of water. The bricks made by the machine appeared to be heavier than the ordinary hand-made bricks of the same dimensions; and he enquired whether

their power of absorption had been ascertained as compared with ordinary bricks.

Mr. Oates said he had not measured the absorption of the bricks made by the machine, but believed it would be less than that of hand-made bricks, since it appeared from the fracture of the machine-made bricks that they were more uniformly burned throughout.

Mr. C. May observed that in comparing different bricks it would be necessary to be particular as to the size of the bricks referred to, since there were great differences of size and an entire absence of uniformity in this respect. He found by measurement that among the bricks now exhibited one contained only 85 cubic inches and another as much as 139 cubic inches, whilst the generally received standard of size, measuring $9 \times 4\frac{1}{2} \times 3$ inches, contained 121 cubic inches. All the expenses of manufacture were directly affected by the size made; and in the case of the small sized London bricks 1 ton of coals was sufficient to burn 3000 bricks, so that the estimate of $\frac{1}{2}$ ton of coal per 1000 was too high in that case. As to absorbing power also the same discrepancies would be observed in consequence of differences of size: but he did not think there was any brick not purely vitrified throughout that would not take up a considerable proportion of water. Ordinary hand-made bricks often took up as much as 1 lb. of water, when tried long enough to become saturated; and if the bricks made in the machine absorbed less in consequence of being harder burned, then a larger quantity of coal must have been consumed in burning them to the greater degree of hardness.

Mr. Clift said the bricks referred to throughout the paper were the large size bricks shown, containing 139 cubic inches; these were made in the machine at Oldbury at a regular rate of 20 good bricks per minute, which was a safe average of several months' continuous work during wet and fine weather. There would necessarily be some variation in size of the bricks made by the same machine, arising from the different degrees of shrinking in burning, which would depend upon the position of the bricks in different parts of the kiln.

Mr. W. Hawkes thought it was important to fix on some standard dimensions for bricks, that they might be fairly compared in strength and other qualities; and suggested the common dimensions

of 9 × 4½ × 3 inches as most suitable. From experiments that he had made on the strength of different sorts of bricks it appeared that the Boston American brick, which was one of the smallest in size, measuring only 7·5 × 3·4 × 2·2 inches, was one of the strongest under a transverse strain, the average transverse strength of four being 2008 lbs.; while the transverse strength of a St. Petersburg brick measuring 10·0 × 4·8 × 2·8 inches was only 880 lbs., both being calculated at 7 inches distance between the bearings. If these were reduced to one common size of 4½ × 3 inches transverse section with 7 inch bearing, the mean strength of the four Boston bricks would be 4942 lbs., and the strength of the St. Petersburg brick 947 lbs. or less than 1-5th of the former. In testing bricks both the transverse and crushing strength should be tried, as the bricks had to stand both strains in practice, but were not equally able to resist them both. The absorbing power of bricks should be tried by 24 hours' immersion in water, which he believed was the practice with some of the London builders, in order to obtain a reliable result by ensuring their complete saturation.

The CHAIRMAN remarked that he had seen a brick-making machine working near Norwich, invented by Mr. Hodson of Hull, consisting of a common pugging mill with the knives or cutters set so as to force the clay through a mould at the bottom, the size of the brick being regulated by a spring platform on which it was delivered and cut off by hand; the machine was driven by a horse and seemed to take but little power and was an inexpensive construction, and he understood it was satisfactory and economical in working.

Mr. OATES said in his early trials upon the plan of the present machine he had made one to be worked by a man with a 5 feet lever, which required very little power to work it with soft clay, and he had still got some of the bricks then produced; the clay was purposely made as soft as for hand-made bricks, but the bricks then required a drying process before stacking in the kiln, just as in hand-making. When the clay was used drier in the machine, so as to save drying afterwards, more power was wanted and an engine had to be employed to work the machine.

He showed a working model of the pressing screw and escape pipe

of the machine, showing the regular action of the vertical screw in forcing out laterally through the horizontal pipe a column of clay of uniform density.

Mr. E. A. Cowper asked what was the cost of the machines, and how many there were at work.

Mr. Oates replied that the cost of the machine was from £150 to £200, exclusive of the engine for driving it. There were now 14 of the machines at work in different parts of the country, some of which had been working regularly for three years. The wear of the screws varied considerably according to the quality of the clay; in one instance the screw had lasted for as many as 2 million bricks, but with a very silicious material it would not last nearly so long, and one screw would not make more than 250,000 bricks with a clay containing much silica.

The Chairman proposed a vote of thanks to Mr. Clift and also to Mr. Oates, which was passed.

The following Paper was then read :—

DESCRIPTION OF A NEW CONSTRUCTION OF HIGH PRESSURE STEAM BOILER.

By Mr. J. FREDERIC SPENCER, of London.

This paper is communicated by the writer with the view of contributing to the general experience in generating steam of high pressure, say of 200 lbs. per square inch, in the belief that whilst the economy of more extended expansion is fully admitted, a safe, durable, and economical generator for high pressures is still a great desideratum. The boiler to which this paper refers was in some of its features invented and worked in America in 1852, and applied to work the steam pump of a fire-engine, lightness and rapid generation of steam being the chief requirements; and in December, 1856, the principle of mechanical circulation, one of the chief features of the boiler, was conceived and introduced by Mr. Benson of Cincinnati, United States, and others. There are now about 45 of these boilers working satisfactorily in America, 10 of them being attached to stationary engines and 35 to steam fire-engines. A boiler capable of safely generating steam of 200 to 300 lbs. per square inch, which has been so successfully and extensively in operation, it was thought would be considered not unworthy the notice of the members of this Institution.

Safety, durability, and economy are the great requirements in a steam boiler; and practical engineers know too well by experience that, whilst it is not difficult to accomplish either of these singly, the combination of the three is extremely so, and especially where the steam to be generated is of very high pressure. Among the various boilers that have been constructed for generating steam of very high pressure, the small tubular form has been chiefly adopted, as being the strongest with the least weight of metal, and as also possessing the additional advantages of affording the largest heating surface in a

given space, and containing almost a minimum quantity of water. One of the most important functions of a steam boiler is regular, uniform, and constant circulation of the water; so that as soon as the steam is formed it shall pass without delay into the steam chamber and the space it occupied be immediately refilled with water. If from any cause this natural action is impeded, two injurious consequences result: namely reduced evaporation and premature destruction of the conducting metal. It has been found that in land and marine boilers, in which there is always such a large amount of water in the boiler compared with the quantity evaporated, there is generally a very defective circulation, as evidenced by slow evaporation and rapid destruction of the conducting metal. In generating steam within small tubes containing a small amount of water, any deficiency of the feed may leave the tubes without water, in contact with a high temperature, and stop entirely or partially the proper circulating action so necessary in generating steam. The uncertainty of what may be termed natural circulation led to the invention and introduction of that which forms the distinctive feature of the boiler now to be described—mechanical circulation: by which ten to twenty times the quantity of water required for steam may be passed through the boiler within a given time.

The new boiler is shown in Figs. 1 and 2, Plates 52 and 53; Fig. 1 is a vertical section through the furnace and steam receiver, and Fig. 2 is a back elevation with part of the tubes in section. Above the furnace F is arranged a series of tubes T of about 1 inch or 1½ inch diameter and of any convenient length; these tubes are enclosed within a brick casing, or if preferred a water space casing, square in plan; they are covered in at the top by the uptake and chimney. Alongside and secured to the casing is the cylindrical steam receiver R, connected direct to the upper portion of the tubes by the pipes L, and to the lower portion of the tubes by the pipe E, the circulating pump P, and the pipe G. The boiler is divided into six distinct vertical sections, as shown in Fig. 2, each of which is separately connected below to a common feed or circulating pipe C communicating direct by the valve box V and pipe G with the circulating pump P, and above to the receiver R by the pipes L. A pipe H is also fixed

between the receiver and the common feed or circulating pipe C, to allow the water in the receiver to pass into the tubes when the pump is not working and in starting the boiler.

The tubes and receiver are in the first instance partially filled with water pumped in by hand, as in other boilers, the communication between the lower and upper portions of the tubes and the receiver being open: the fire is then lighted, and as rapidly as the steam is generated in the tubes it passes through them into the receiver, until the whole of the water is heated and sufficient steam is generated to work the circulating pump. This pump, worked by a steam cylinder, is double-acting and of simple construction, having instead of the ordinary self-acting valves a D slide valve without lap and worked by an eccentric, so that its continuous action can be thoroughly relied on; this arrangement has in practice given every satisfaction. It will be evident that a small amount of power is required to work the circulating pump, since the pressure is almost equal on each side of the piston; so that whether this pressure be 100 or 500 lbs. per square inch, only the friction of the water has to be overcome in effecting the circulation. A boiler of 100 nominal horse power would require a circulating pump of only 7 inches diameter and 12 inches stroke, making 50 revolutions per minute. In addition to the circulating pump there is the ordinary feed pump attached to it, to supply the deficiency caused by the evaporation; and the ordinary feed pipe may be connected either to the circulating pump, as at I, Figs. 1 and 2, or to the pipe C, or to the receiver R. The water gauge is fixed on the receiver, and indicates the amount of water therein for the regulation of the feed. As soon as sufficient steam is generated to work the circulating pump, which in ordinary cases occupies about 20 minutes from cold water, the full working action of the boiler commences; and supposing 10 cubic feet of water are evaporated per hour, about 100 cubic feet are passed through the circulating pipe C and the tubes by the circulating pump. This 100 cubic feet per hour is discharged from the upper portion of the tubes into the receiver as mixed water and steam, the water falling to the bottom of the receiver and the steam remaining in the upper portion or steam space. It might be supposed that the steam would not be

separated from the water with sufficient rapidity, and that very wet steam would be supplied: but practice and experience have proved that this is not the case; the separation is both rapid and distinct, and even when the water in the receiver has been allowed to rise to within a few inches of the top, the steam obtained has been quite as free from water as that usually supplied by ordinary land boilers.

Each section of the boiler has its own separate connexion with the receiver, and also with the common circulating pipe C; and the flow of water through the latter connexions is regulated to any extent either by simple contractions or by cocks or valves; the contractions however are preferred. There are also cocks or stop valves on each of the upper connexions to the receiver, so that any section of the boiler may be shut off in case of injury, without in any way affecting the efficient working of the remaining sections. This is a most important feature of safety, and provides for easy repair either at the time of injury or at any subsequent period when convenient.

Figs. 3 and 4, Plate 53, show the tubes to a larger scale; they are screwed with a right and left handed thread so as by one movement to draw the two end bends together, and by this plan the union of the tubes in each section is performed without difficulty. It will also be noticed that each section of tubes can expand to any extent, being suspended on the vertical plates S by a small lug on each bend rivetted to them. For sweeping, cleaning, or removing any one of the sections hinged doors D are placed in front of the boiler, thus giving easy access at any time to any portions of the tubes. These boilers have been made both with brick casings, and water space casings; but the former plan is preferred on account of economy of first cost, safety, and improved combustion: when the casing is a water space, it may form the receiver.

Figs. 5, 6, and 7, Plate 54, show the arrangement of the boiler for marine purposes, with a distinct set of tubes A for superheating or drying the steam after it has left the receiver.

The general construction and working action of the boiler having been described, a few remarks may be added as to its safety, durability, and economy.

Safety :—there can be no question of the great strength of small cylindrical tubes of 1 or 1½ inch diameter; and as the receiver is not acted on by any high temperature, it can be maintained in full strength for an almost unlimited period. In consequence of the small amount of water in the tubes but little injury could arise from their giving way; and the receiver being removed from any external source of heat could not in the event of its bursting produce the dangerous percussive action resulting from the sudden release of highly heated water in a heated flue. Another element of safety is the facility with which any injured section can be disconnected from the rest of the boiler.

Durability :—the only part of the boiler subject to great heat is the lower portion of the tubes, and it will be readily seen that the strong current supplied by the circulating pump tends to prevent not only deposit, but also any injury arising from want of water in the tubes. The tubes in one of these boilers that had been in constant work for 18 months with water largely impregnated with lime and other impurities were found on examination of several of them to be perfectly free from scale, any solid matter passing into the receiver from which it was easily removed. In order to ascertain the effect of working the boiler with salt water, some experiments have been made with one constructed in Newcastle by Messrs. Hawthorn. This boiler was formed of wrought iron tubes, 1 inch inside diameter, and had about 340 square feet of heating surface and 9 square feet of grate surface: it was kept in constant operation for 14 days and nights under a pressure of 80 lbs. per square inch, with salt water having about 5-33rds or 15 per cent. of salt in it, a saltness greatly in excess of that considered safe in marine boilers. Upon examination the lower tubes were found with an internal scale of 1-16th inch, whilst in the upper tubes a scale was hardly perceptible. This experiment was made with the view of trying how much scale could be deposited under the most unfavourable circumstances; and the result clearly proved that with the ordinary saltness in marine boilers the system of mechanical circulation would enable these boilers to work safely for a lengthened period. Although it is not intended at present to recommend the boilers to be continuously worked with sea water, it is satisfactory to know that, when used in combination with surface condensation, any

temporary cessation of the pure water supply cannot injuriously affect them.

Economy of Fuel:—it is well known that efficient combustion, thin conducting metal, large heating surface, and regular circulation will give a large evaporative duty. The result of some experiments made in the United States in June last gave an evaporative duty of 11 lbs. of water per lb. of fuel: it is however but fair to state that these experiments were made under unfavourable circumstances as to the working of the boiler.

Economy of Weight:—it is in marine boilers especially that weight is objectionable; and an ordinary marine boiler with 2000 square feet of heating surface is here compared with one of the same heating surface constructed on this tubular and circulating plan:—

	New boiler.	Ordinary boiler.
Weight of boiler, including brickwork, without water	22 tons.	20 tons.
Weight of water in boiler	2 ,,	19 ,,
Total weight of boiler and water	24 ,,	39 ,,

It will thus be seen that 40 per cent. of weight is saved; and in this comparison the heavy brick casing of the new boiler has been included together with the receiver and connexions.

Economy of Space:—taking again the new boiler with 2000 square feet of heating surface and an ordinary marine boiler having the same heating surface, the spaces occupied are as follows:—

	New boiler.	Ordinary boiler.
Floor area	80 square feet.	130 square feet.
Cubic space	960 cubic feet.	1560 cubic feet.

This comparison is greatly in favour of the new boiler, showing a saving of nearly 40 per cent. both in floor area and cubic space occupied.

Economy of Cost and Repair:—as to the cost of construction, experience has proved that in all cases the new boilers with circulating pump and receiver complete are made at a less cost that those of the ordinary tubular construction; and with reference to the cost of repair, it is almost entirely confined to the tubes and brick casing and therefore cannot be serious in amount.

One other advantage has to be referred to in these boilers in comparison with those in general use: namely rapidity in raising

steam from cold water. In October 1858 some interesting experiments were made at St. Louis, United States, to test seven steam fire-engines, six of which had boilers on the circulating principle: in these six the steam was raised to 60 lbs. from cold water within 6 minutes. This is easily accounted for by the small quantity of water acted upon by the fire; but in general practice it is considered advisable to have a larger reserve of water, so that from 20 to 45 minutes may be necessary to raise steam. As the result of actual experience the following proportions have been arrived at for efficient generation of steam: for land boilers having 200 to 1000 square feet of heating surface there should be 1 cubic foot of steam and water space to every 22 square feet of heating surface; whilst in boilers having above 1000 square feet of heating surface the proportion should be 1 to 25: for marine boilers the proportion of steam and water space to the heating surface should be 1 to 27.

Mr. J. Inshaw thought the tubular construction of boilers had several advantages, in compactness and lightness, and in increased extent of heating surface with diminished thickness of the conducting metal. He had made several tubular boilers many years ago, consisting of a series of concentric spiral coils of tubes placed upright in the furnace, each coil containing three spiral tubes of coarse pitch, and the coils being right and left handed alternately; there were 22 tubes in all, each about 27 feet long, of copper, $1\frac{1}{4}$ inch diameter inside with $\frac{1}{16}$ inch thickness of metal. The spirals started at the bottom from a vertical water vessel placed at the back of the furnace, and returned at top into the top of the same vessel, which communicated by pipes with a receiver situated over the furnace and forming the steam chamber of the boiler, through which the uptake flue to the chimney passed for the purpose of superheating the steam; the water was kept 4 inches deep in the receiver, so as to ensure the tubes being always full of water. One of these boilers had been put up in Birmingham, supplying steam to a pair of 6 inch cylinders, working at about 6 horse power.

The CHAIRMAN asked how long the boilers referred to had been at work, and how long the spiral tubes lasted.

Mr. J. INSHAW replied that the boiler erected in Birmingham had continued at work for two years without requiring any repairs to the tubes, but it was then heated red-hot and burnt down through wilful neglect on the part of the stoker. The firegate was hinged at the back and held up in front by a chain attached to a fusible plug in the receiver above, with the intention that the fire should be dropped in case of the water ever falling so low as to uncover the tops of the tubes; but the stoker having on one occasion purposely propped up the grate and neglected to fill up the supply of water, the whole of the tubes were burnt down. He had at first feared that the circulation of water through the tubes in regular work would not be sufficient to prevent their being burnt down, as there was only the natural circulation of the water to produce the necessary current through the tubes; but the tubes being each a continuous spiral, without any sudden turns, presented less obstruction to the passage of the water through them than would be the case in a boiler constructed like that described in the paper. One of the connecting pipes to the receiver had been replaced by a glass tube, that the circulation might be seen while at work; and a continued froth of mixed water and steam was seen to pass up into the receiver from the water vessel. The copper tubes in these boilers had proved durable, and did not become choked with deposit as he had feared would be the case; for on cutting one of them in two after six months' work with fresh water there was found to be very little incrustation of deposit. The rapidity of raising steam in the boiler was remarkable as compared with boilers of the ordinary construction, steam being raised from cold water in 12 to 16 minutes easily; and the boilers had proved economical in fuel, on account of the superior conducting power of the thin copper tubes. In the boiler described in the paper he thought it would have been better to place the receiver higher up, above the level of the tubes, and expected that would give drier steam.

Mr. J. MANNING thought there were a great number of joints in the boiler shown in the drawings, and feared the cast iron bends would suffer from expansion and contraction and be difficult to keep tight;

it was a disadvantage in a boiler to have to depend upon a great number of joints all keeping sound and tight, and he enquired what was the amount of wear and tear in the boiler. He was much astonished at the extraordinary rapidity of raising steam that was stated in the paper, in so short a time as 6 minutes from cold water, and asked what fuel was used; in ordinary boilers the smoke from either wood or coal would hardly be got rid of in that time. The amount of incrustation in the tubes seemed remarkably small in the boiler described; for he had known of tubes of 1 inch inside diameter being made up to only ⅛ inch diameter in two to six weeks' time.

Mr. Spencer said the incrustation in the tubes would be materially prevented by the mechanical circulation of the water, which formed the main feature of the boiler now described; as long as the circulating pump continued at work the circulation of water was kept up and there was sufficient power in the current of water to sweep out any deposit from the tubes, so that little injury could result to them from that cause. With regard to the expansion of the tubes, no difficulty was experienced with the joints or cast iron bends, and there was as much freedom for expansion as in a coiled spiral tube. The arrangement of spiral coils of tubing that had been mentioned might answer for a small boiler, where a small amount of heating surface was sufficient; but he thought it would not be practicable for a large boiler requiring from 3000 to 4000 square feet of heating surface. In the boiler described in the paper great facility for repairs was afforded by its division into a number of independent sections, each suspended by a centre attachment, so that any section could be detached and withdrawn without interfering with the rest of the boiler. As to the rapidity of raising steam, this depended mainly on the total quantity of water in the boiler, as the whole of it had to be heated to the boiling point before any steam was raised; and by diminishing this total quantity of water the time required for raising steam might be reduced to any extent desired. He remembered a locomotive for common roads being tried several years ago, in which steam was raised in 12 minutes from cold water, as there was but a very small quantity of water in the boiler. In the present boiler the quantity of water was very much less than in ordinary

boilers; and the area of heating surface being at the same time increased by the tubular construction, the time necessary for raising steam was greatly reduced. In the case of the steam fire-engines to which this boiler was originally applied, a prize had been offered for the engine which should raise steam and throw a stream of water to a distance of 200 feet in the shortest time from the moment of lighting the fire with cold water in the boiler: in one instance this had been done with one of these boilers in less than 5 minutes, only 4 mins. 50 secs., the fire being made with the most rapidly burning materials, light pine wood and pitch.

Mr. E. A. Cowper remarked that the tubular construction of boiler certainly afforded great facility for getting up steam in a short time, owing to the extent of heating surface; and by reducing the quantity of water in the boiler the rapidity of raising steam might evidently be still further increased. He remembered an American fire-engine boiler that gained the prize for rapidity in raising steam, which was constructed mainly of pipes, one pipe forked into two and these again each into two more; but he did not think any such construction of boiler was practically useful for ordinary purposes, and it appeared applicable only for such cases as steam fire-engines, where the great points of importance were rapidity of raising steam and lightness of construction; in such instances durability was a minor consideration, and it did not matter so much if the boiler were burnt out after a short time of work. For ordinary use however he thought it would not be safe to have so small a quantity of water in the boiler; for to obtain regularity in the pressure of steam a considerable quantity of water was required as a reserve to fall back upon in case of deficient firing or over-firing. With respect to the principle of employing mechanical means to produce an artificial circulation of the water, he thought natural circulation was the safest to be depended upon; for if the circulating pump should get out of order or stop working from any cause, the whole of the tubes would be exposed to be burnt down, since the circulation through them would cease.

Mr. Spencer thought there was not any real ground for objection against the use of machinery for the purpose of generating steam,

since experience proved that dependence was already placed with safety upon the constant action of simple machines under various circumstances. Where an efficient machine could be obtained he would prefer in some cases, and in the present instance, to rely upon it rather than upon an action produced by natural causes which might be liable to accidental interference: many good machines it was known would keep at work for 20 years without failing; and in the present instance he considered so simple a machine as the circulating pump might safely be relied upon for regular working. The principle of mechanical circulation carried out in this boiler appeared to him one of great importance, and worthy of special attention as a valuable improvement in steam boilers, since the circulation in ordinary boilers was so defective.

Mr. Benson said he had been practically acquainted with the working of tubular boilers for many years; and all previous boilers having been dependent entirely upon natural circulation of the water, it had occurred to him that tubular boilers in particular could not prove successful in working unless a constant circulation were maintained through the tubes by mechanical means, so as to be unaffected by accidental circumstances; the uniform mechanical circulation would also enable steam to be raised more rapidly, and the rate of evaporation would be rendered more uniform. In a tubular boiler constructed with spiral tubes he should expect the tubes would last but a short time with natural circulation, if the evaporation were at all rapid, as the steam would be apt to keep back the water from the surface of the tubes; and such an arrangement could be made successful only by the adoption of a forced circulation of the water through the tubes, as he considered mechanical circulation was the essential feature of the tubular boiler. With the employment of mechanical circulation the tubes of the boiler described in the paper had been found to be remarkably free from incrustation; on examining several of them after 18 months' work the interior surfaces presented the clear grey appearance of clean iron without any signs of dirt, showing plainly that any deposit contained in the water was effectually cleared out of the tubes by the mechanical circulation and carried over into the receiver.

In the first attempts at designing the boiler a series of volute coils of tubes had been tried with about 20 coils, the lower tubes being $\frac{3}{4}$ inch diameter and increasing in diameter to 2 inches in the top coil: an arrangement of forked tubes such as had been referred to was also tried, but with these divided tubes it was found impossible to keep up a regular supply of water to all the tubes by the simple feed pump, and plain straight tubes were therefore substituted. There was still however too much hot water constantly in the receiver and too little water in the tubes, on account of the impossibility of keeping the tubes well filled with water by means of the natural circulation alone; and the idea of a forced circulation of the water through the tubes then occurred, and was carried out by the addition of a small circulating pump. Little power was required to work this pump, as it was only 3 inches diameter with a 10 inch stroke and there was the same pressure of steam on both sides of the pump, the only resistance to be overcome being the friction of the water in its passage through the tubes. The sharp bends at each end of the tubes increased the resistance, but had the advantage of impeding the motion of the water and thereby ensuring a thorough contact of the water with the entire extent of heating surface. The screwed ends of the tubes were made slightly conical, so as to jam tight into the cast iron bends, and at first a little linseed oil was applied to make the joint thoroughly steam-tight; but this was found not to be necessary, and it was only requisite to take care the screw threads were clean in screwing together, and then after a few days' working the joints were so tight that they frequently could not be unscrewed, but the ends of the tubes were twisted off before the screws would stir. In two boilers containing each 720 joints screwed in this manner, not one out of the whole 1440 joints leaked after first putting together. For replacing a defective tube in any section of the boiler, the union joints at top and bottom connecting it with the receiver were unscrewed, and the entire section taken out in about 5 minutes; the tube was then cut off at each end near the socket, and the two remaining end pieces were got out by cutting a longitudinal chase in them with a chisel and then collapsing them with strong tongs, without damaging the screw threads in the socket. The new tube to be put in was made

in two lengths joined by a long screwed socket, to allow of getting it in without disturbing the other tubes. The whole operation was done in about 20 minutes, as quickly as a tube could be replaced in ordinary tubular boilers. In the first boilers made the tubes had been placed rather too close together, with only ¾ inch spaces, which did not allow sufficient draught between them; they were now fixed with 1¼ inch vertical spaces, but the horizontal spaces were left ¾ inch. Good combustion of the fuel with this construction of boiler was obtained by having the lowest row of tubes about 3 feet high above the grate.

The new boiler was specially designed at first for steam fire-engines, and was then made to contain only 3 cubic feet of water in the tubes and 6 cubic feet in the whole boiler. The boiler was kept standing ready for use, with no water in the tubes; and immediately that the fire-bell rang, a fire of very light pine wood was lighted under the boiler and half the water turned into the tubes; the engineman then worked the circulating pump by hand, and in 5 minutes the engine was ready for throwing water with 60 lbs. steam. In one of the trials made as to rapidity of raising steam from cold water, steam of 60 lbs. pressure was raised in as short a time as 4 mins. 35 secs. In all such cases the amount of water in the boiler was purposely very small; but boilers intended for stationary engines would have a larger quantity of water, and might be constructed to contain any quantity that was thought suitable: the time required for raising steam would then of course be increased, and for ordinary stationary engines 40 or 45 minutes might be required for getting up steam. A stationary boiler of this construction with 400 square feet of heating surface had been at work at Cincinnati for 16 months before he left America in June 1858, supplying steam to an engine driving a machine shop, and both engine and boiler were attended to by a boy 14 years old: for stopping during the dinner hour it was only necessary to stop the circulating pump, damp the fire, and shut the firedoor and ashpan, and the boiler then stood for an hour without any injury to the tubes.

With regard to the evaporative duty of the new boiler, an experiment had been made with one of the boilers in a steam fire-engine in America, with 300 square feet of heating surface, and it evaporated 11 lbs. of water per lb. of coal; the pressure of steam was

80 lbs. per square inch, and the fuel bituminous coal. In this case the draught through the furnace was weak, the chimney being only 6 or 7 feet high.

Mr. E. Jones asked whether any of the boilers were at work yet in this country, as he remembered having seen one in process of manufacture at Wednesbury more than a year ago.

Mr. Spencer replied there were not any of the boilers working at present in this country, but two were being made, which would be got to work in London shortly. One of the boilers had been constructed at Newcastle, and had been tried there for 14 days continuously with salt water; and only $\frac{1}{16}$ inch thickness of deposit was found in the lower tubes at the end of that time, with scarcely any scale in the upper tubes, though the water used was much more salt than was allowed in marine boilers.

Mr. J. Inshaw observed that in reference to rapidity of raising steam he did not think this was a point of much advantage for ordinary stationary boilers, because with so small a quantity of water the pressure would go down again as quickly as it was raised, and would be more affected by irregularity in the firing. He enquired how the proper proportion of water was ensured to each section of the new boiler without a separate circulating pump for each section.

Mr. Benson replied that the apertures of the branch pipes leading to each section of the boiler were regulated in area of passage to the required extent for ensuring an equal distribution of the water, the openings nearest the circulating pump being the smallest. Cocks had also been used for the purpose on each branch in some of the boilers, but he preferred to regulate the supply by the size of the aperture, by which the distribution of water was made permanently correct. The circulating pump worked with a simple slide valve with no lap, which kept up an uninterrupted current of water.

Mr. Spencer remarked that there had been a good practical trial of small tubes in the hot-water warming apparatus employed by Mr. Perkins of London, who had now had one set of the tubes in constant work for 12 years with only natural circulation of the water, without any injury to the tubes; it thus appeared that even without the adoption of mechanical circulation tubes would last for a long time

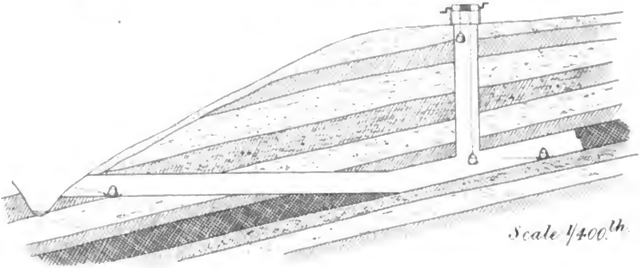
without choking if taken care of, but with mechanical circulation any liability to incrustation was still further diminished.

Mr. Benson observed that an essential point in this construction of tubular boiler was the use of a receiver from which the steam was drawn, for it would be impracticable to work such a boiler without the receiver, as the steam could not be obtained dry if taken off direct from the tubes; and by increasing the size of the receiver the quantity of water contained in the boiler could be increased to any extent desired, while the area of heating surface remained unaltered.

The Chairman proposed a vote of thanks to Mr. Spencer for his paper, and also to Mr. Benson, which was passed.

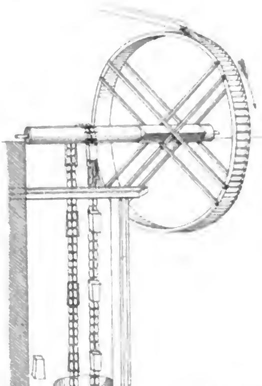
The meeting then terminated.

Fig. 1. *Early Plan of Coal Mining 1100 to 1600.*



Scale 1/400th.

Fig. 2. *Chain Pump 1700*



Scale 1/100th.

Fig. 4. *Early Pumping Machine with Cranks 1550.*

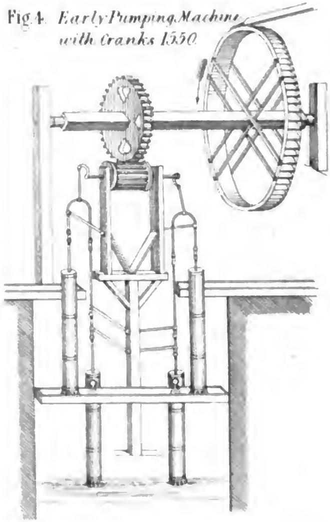
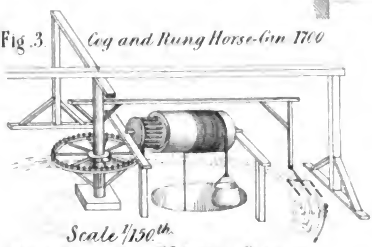
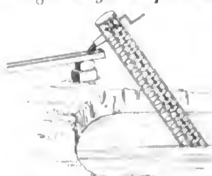


Fig. 3. *Cog and Rung Horse-Gin 1700*



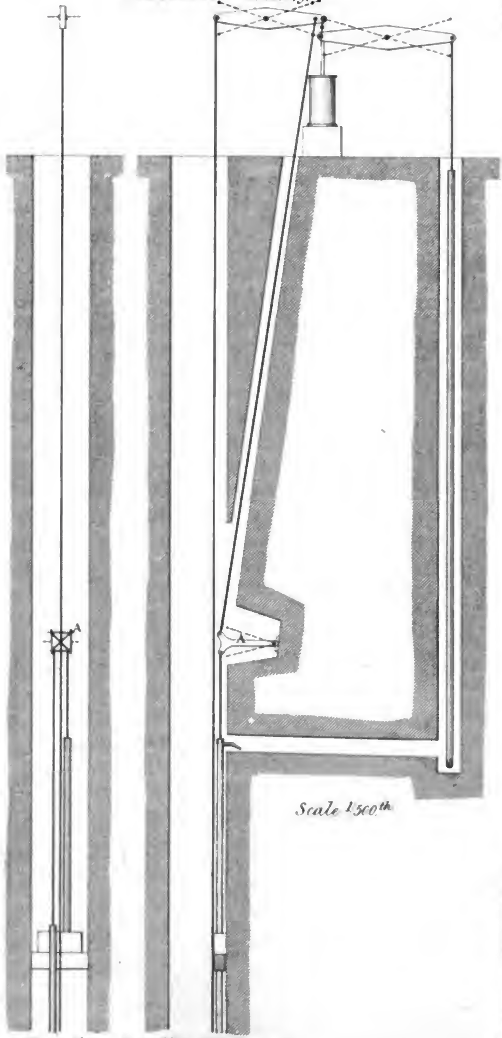
Scale 1/150th.
(Proceedings Inst. M. E. 1859. Page 15.)

Fig. 5. *Rag Pump 1700.*



Scale 1/100th.

Fig. 6. *Pumping Engine with V Bob. Backworth Colliery.*



Scale 1/500th

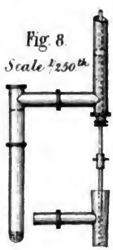
Fig. 7. *Direct-acting Pumping Engine. Burradon Colliery.*

Scale 1/500th

Plan.

Fig. 8.

Scale 1/250th



(Proceedings Inst. M.E. 1859. Page 15)

Fig. 9. *Pumping Engine. Hartley Colliery.*

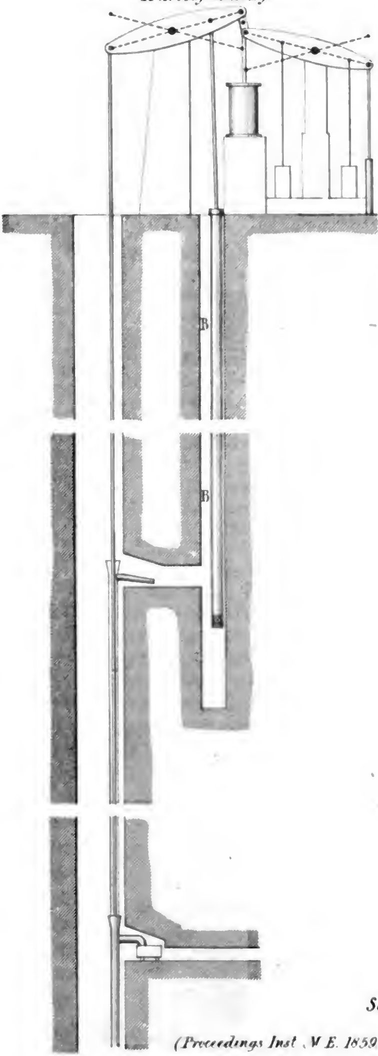
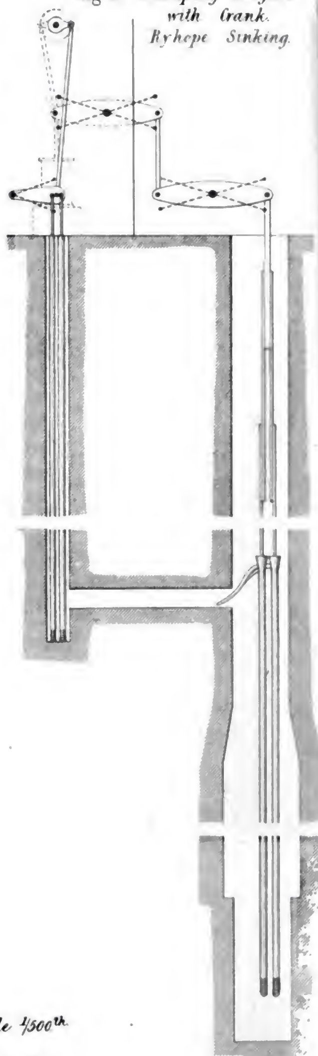


Fig. 10. *Pumping Engine with Crank. Ryhope Sinking.*



Scale 1/500th

(Proceedings Inst. M. E. 1859. Page 15.)

Dowlais Water Balance Machine.

Fig 11. *Elevation*

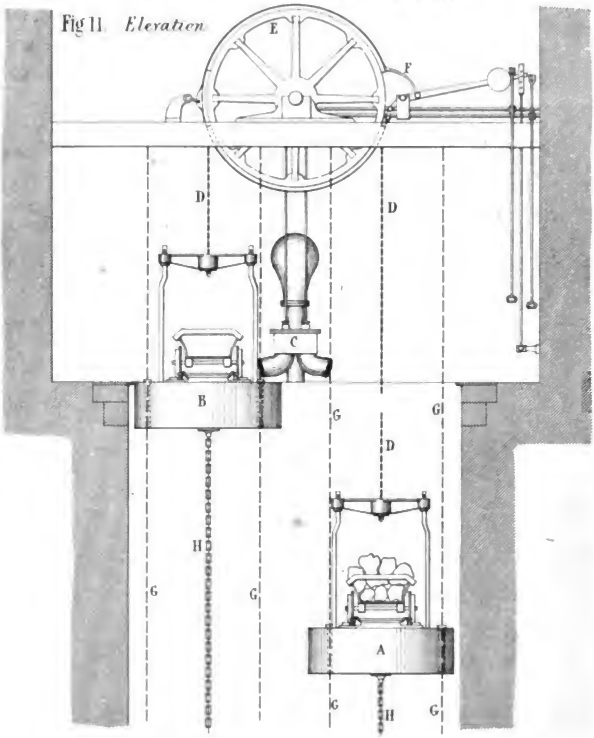
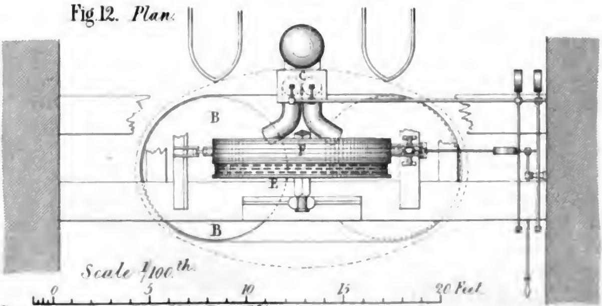


Fig 12. *Plan*



Scale 1/100th

0 5 10 15 20 Feet

(Proceedings Inst. M.E. 1859. Page 15.)

MINING MACHINERY.

Plate 5

Smeaton's Double Water Wheel Winding Engine

Walker Colliery 1778

Fig. 13 *Elevation*

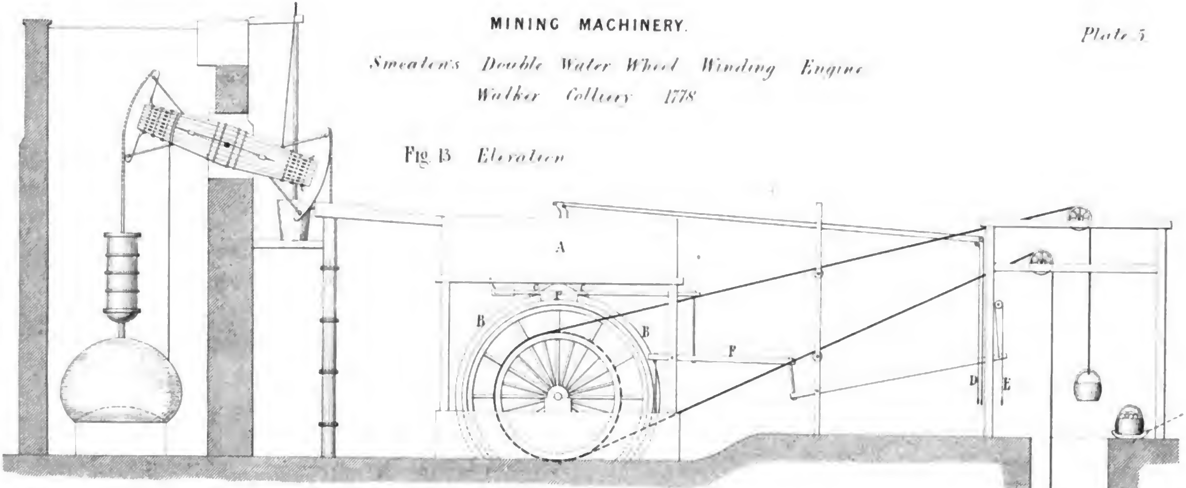
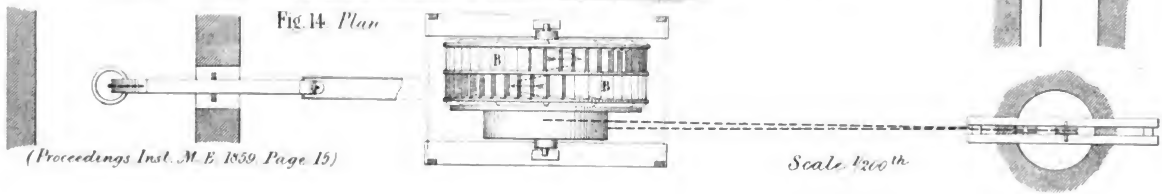


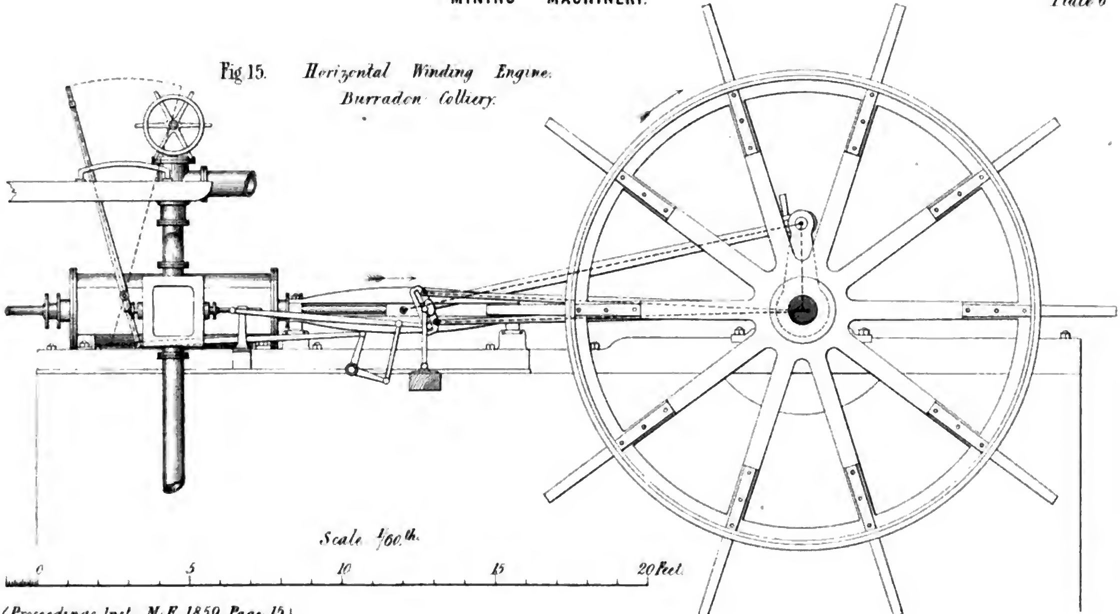
Fig. 14 *Plan*



(Proceedings Inst. M. E. 1859. Page 15)

Scale 1/200th

Fig 15. *Horizontal Winding Engine. Burradon Colliery.*



(Proceedings Inst. M. E. 1859. Page 15.)

Struvé's Mine Ventilator.

Fig. 16. *Sectional Elevation.*

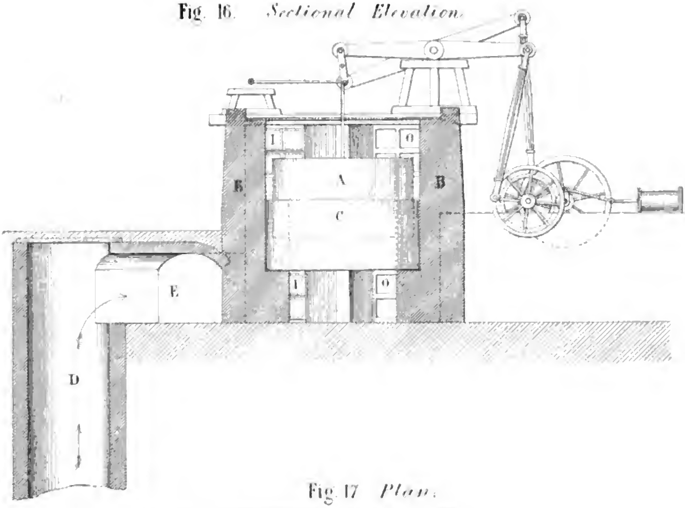
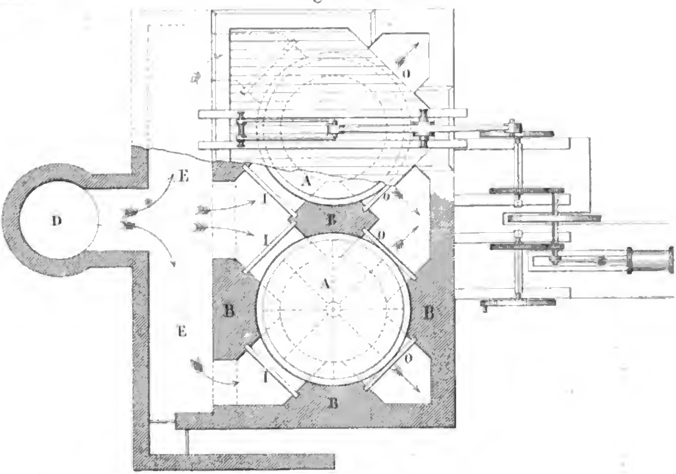


Fig. 17 *Plan.*



Scale $^1/_{250}$th.

10 5 0 10 20 30 40 50 Feet

(Proceedings Inst. M. E. 1859. Page 15.)

Struve's Mine Ventilator.

Fig. 18. *Vertical Section.*

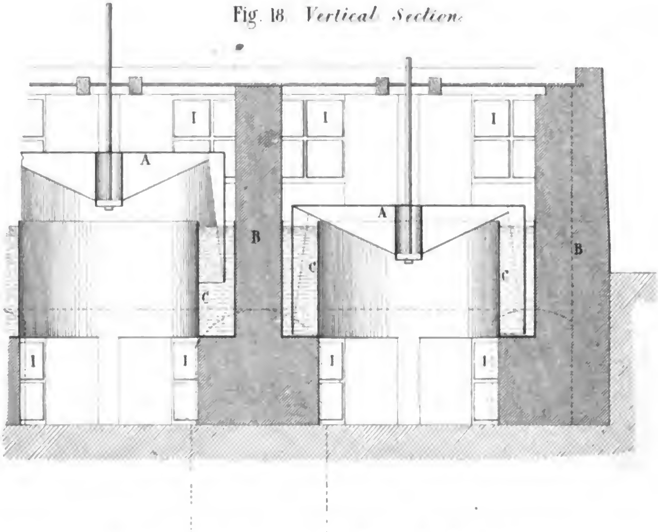
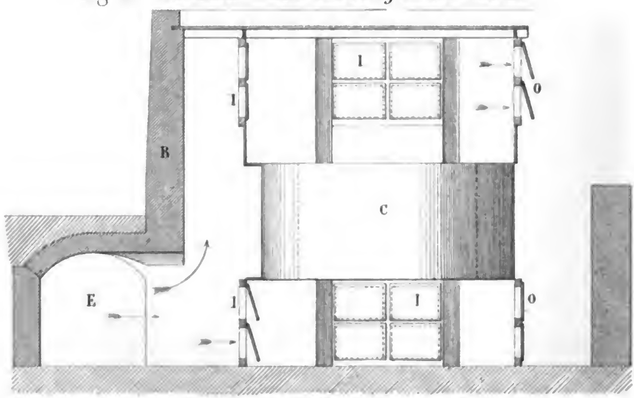


Fig. 19. *Vertical Section through Air Valves.*



Scale 1/150th

10 5 0 10 20 30 *Feet.*

(Proceedings Inst. M.E. 1859. Page 15)

Fig. 1. *General View of Brick Machinery.*

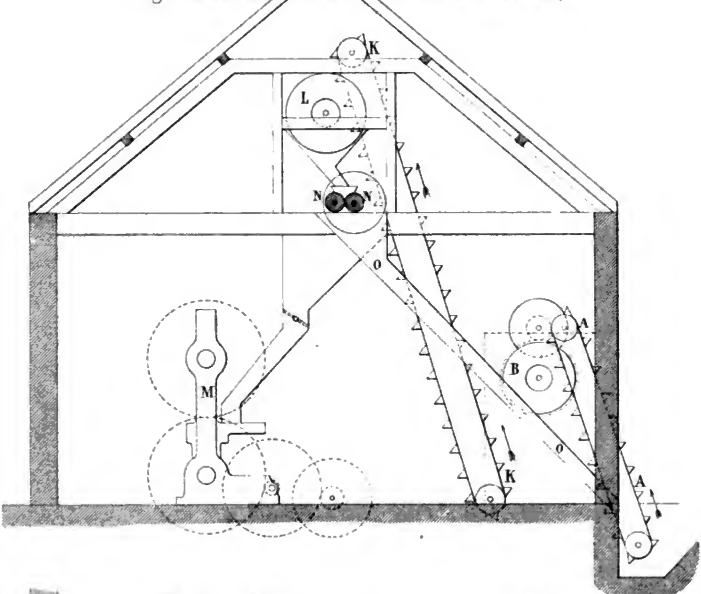
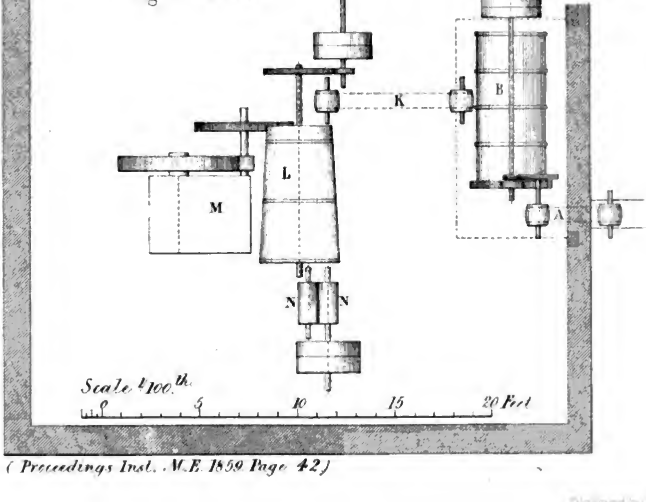


Fig. 2. *Plan.*



Scale 1/100th

0 5 10 15 20 *Feet*

DRY-CLAY BRICK MACHINERY.

PULVERISER.

Fig. 3. Transverse Section. Fig. 4. Longitudinal Section

SIFTER.

Fig. 5. Transverse Section. Fig. 6. Side Elevation

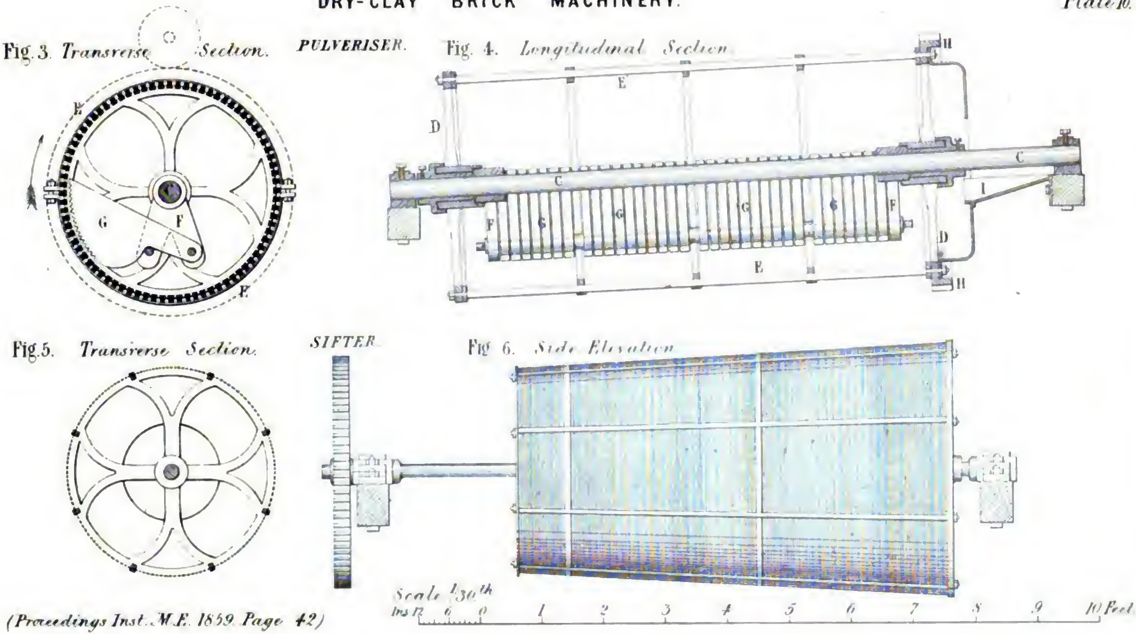
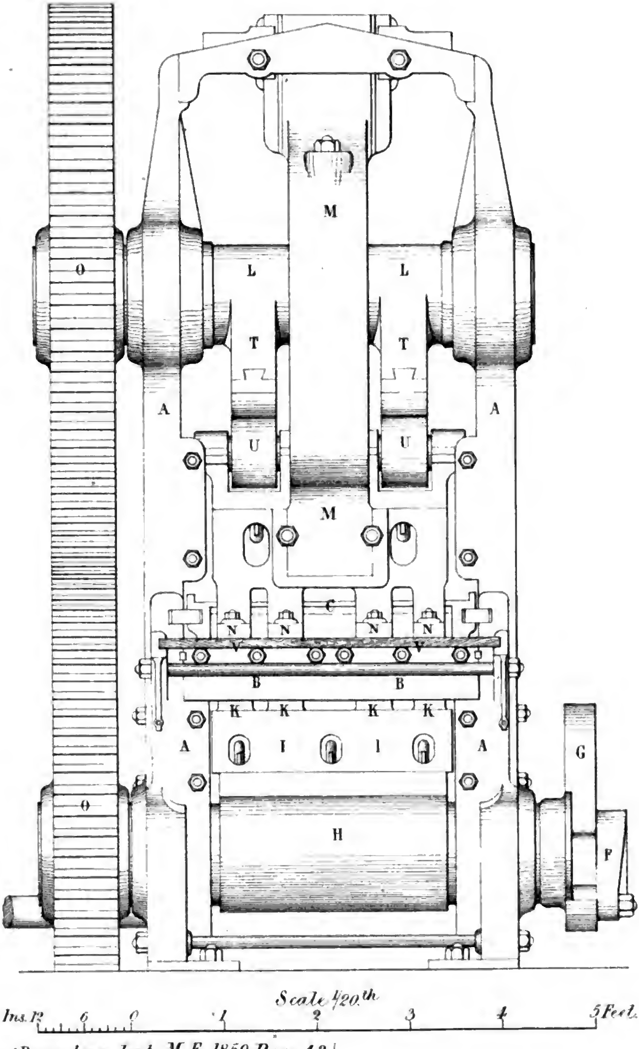


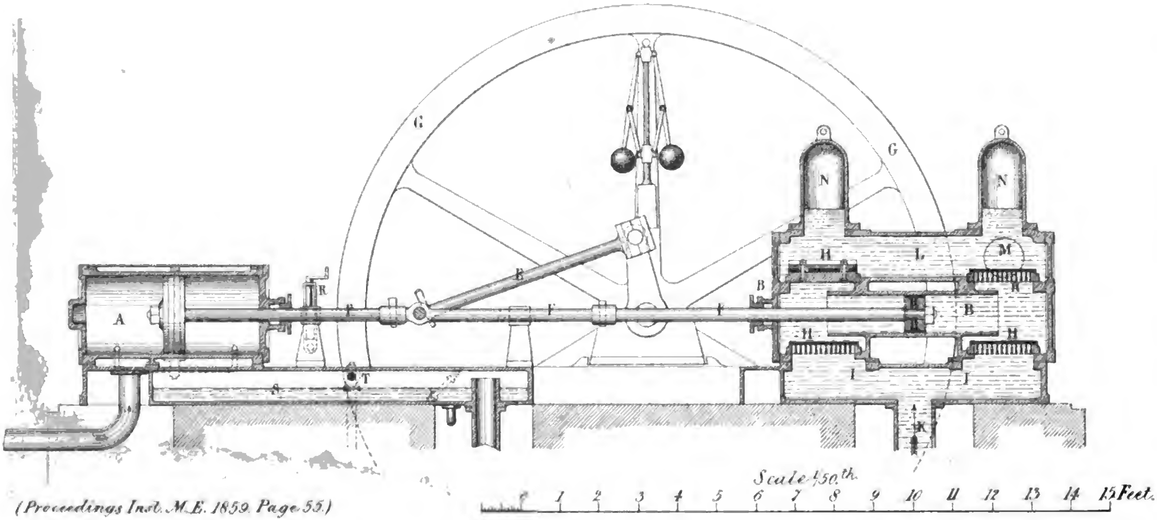
Fig. 7. Front Elevation of Brick Press



(Proceedings Inst. M.E. 1859. Page 42.)

NEWCASTLE PUMPING ENGINE.

Fig. 1.* *Longitudinal Section of Engine and Pump.*



(Proceedings Inst. M.E. 1859. Page 55.)

NEWCASTLE PUMPING ENGINE.

Plate 14.

Fig. 3. Transverse Section of Pump.

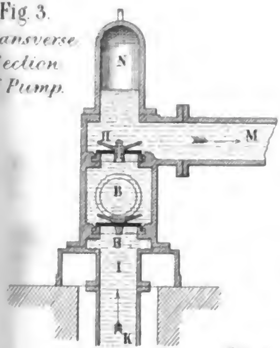


Fig. 5. Transverse Section of Pump Valve.

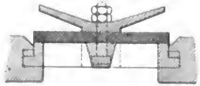


Fig. 6. Longitudinal Section of Pump Valve.

Scale 1/15th

Fig. 4. Transverse Section of Steam Cylinder.

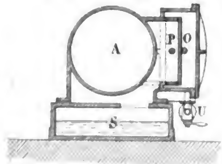
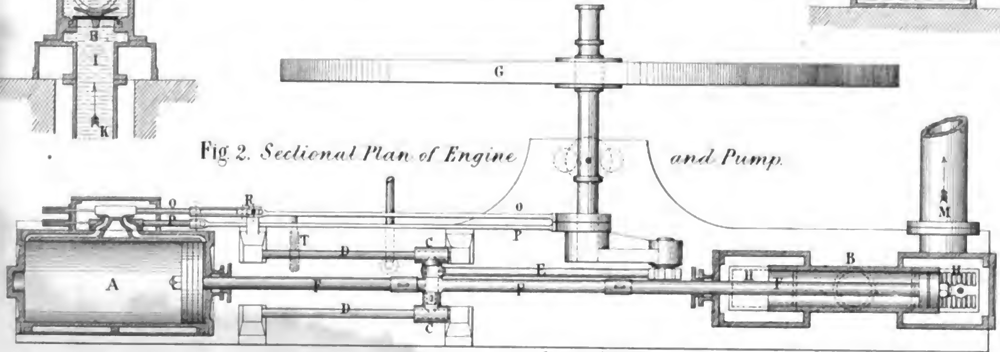


Fig. 2. Sectional Plan of Engine and Pump.



Scale 1/50th

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 Feet.

Fig. 7. *Elevation of Expansion Gear and Valves.*

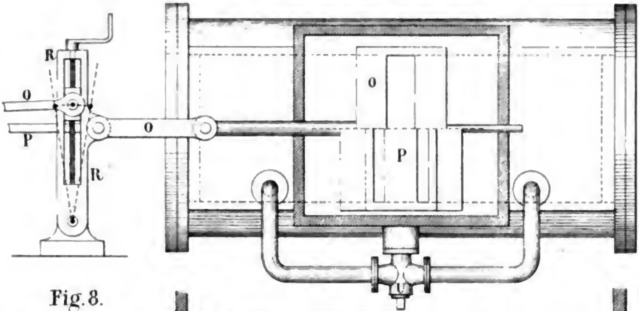
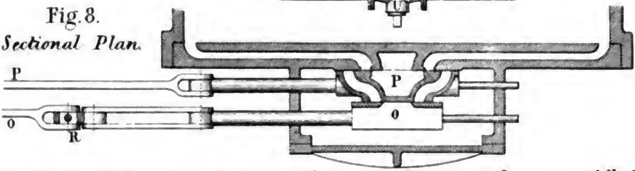


Fig. 8.
Sectional Plan.



Scale 1/20th. Ins 12 6 0 1 2 3 4 *Feet.*

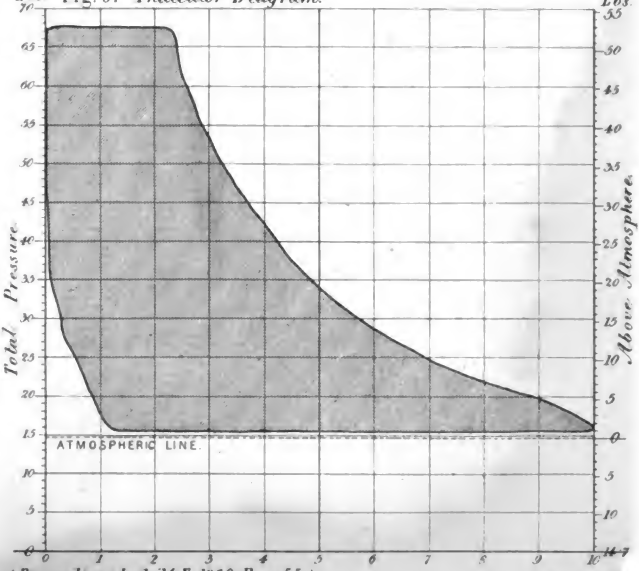
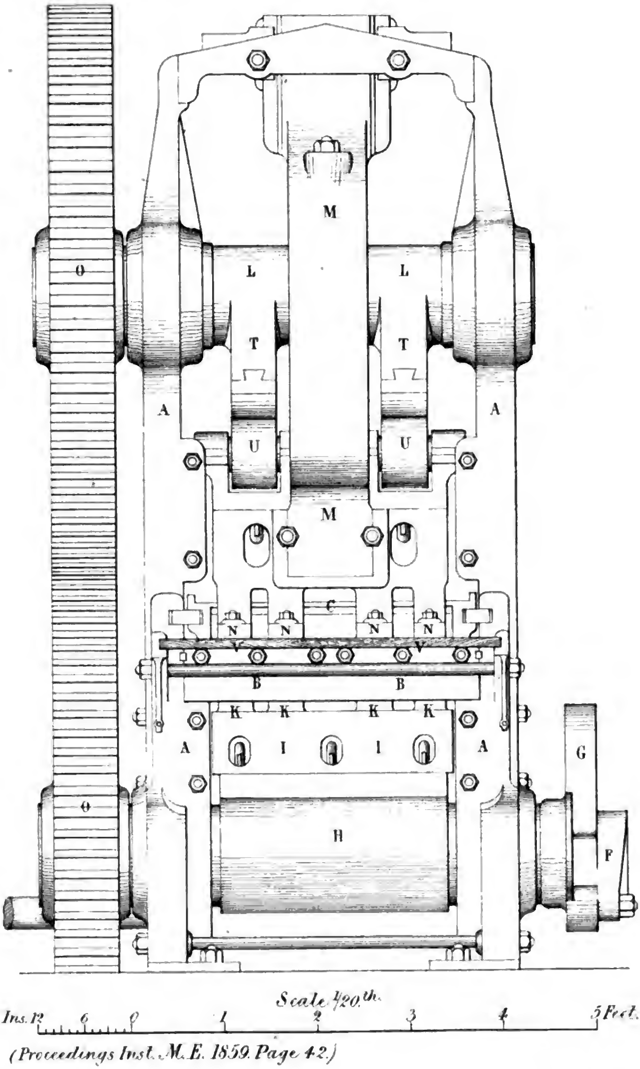


Fig. 9. *Indicator Diagram.*

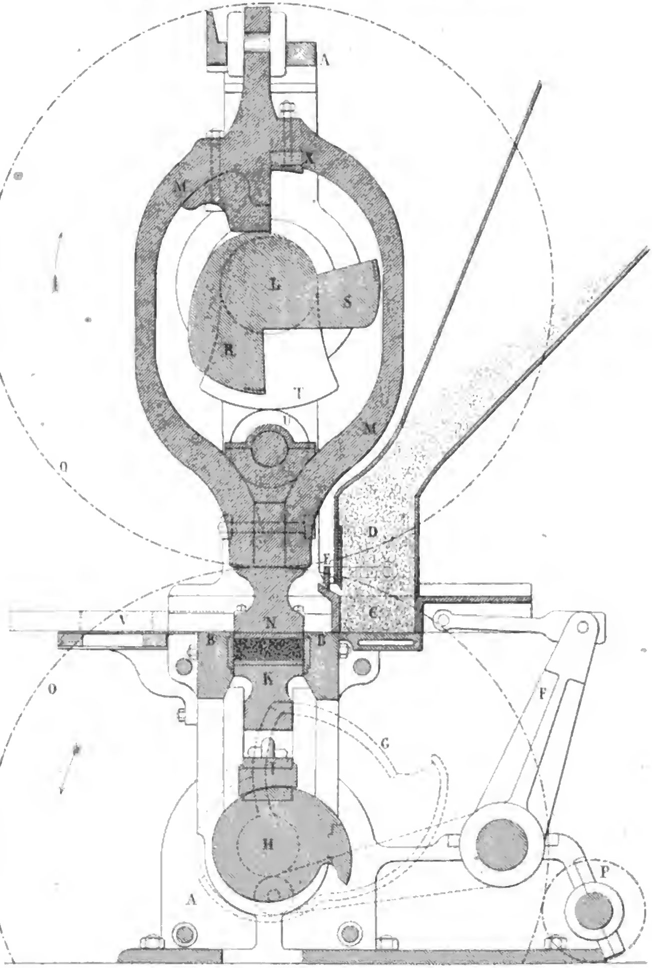
(Proceedings Inst. M.E. 1859. Page 55.)

Fig. 7. *Front Elevation of Brick Press*



(*Proceedings Inst. M. E. 1859. Page 42.*)

Fig. 8. *Transverse Section of Brick Press.*



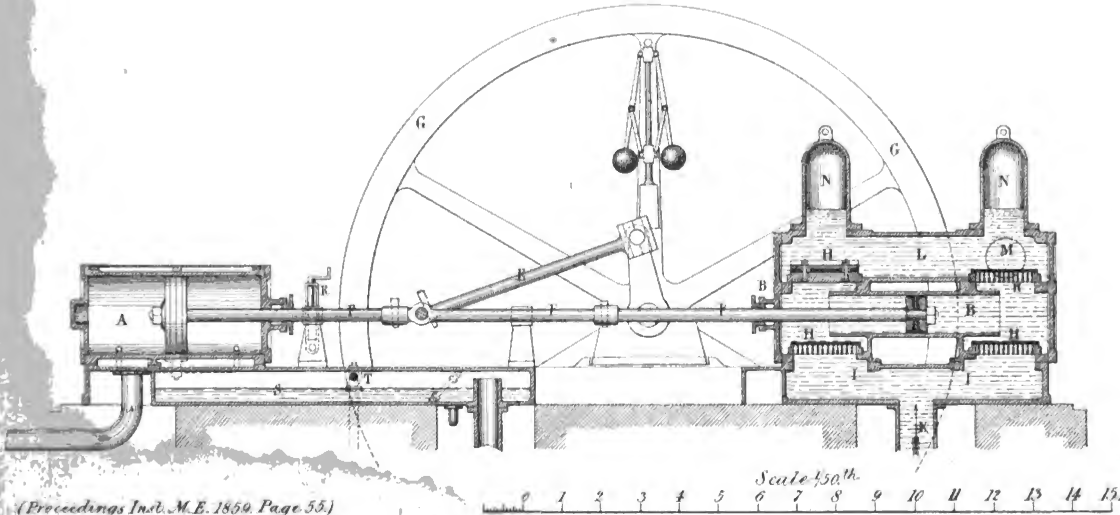
Scale 1/20th

Ins. 12 6 0 1 2 3 4 5 Feet

(Proceedings Inst. M. E. 1859 Page 42)

NEWCASTLE PUMPING ENGINE.

Fig. 1. *Longitudinal Section of Engine and Pump.*



(Proceedings Inst. M.E. 1859. Page 55.)

NEWCASTLE PUMPING ENGINE.

Plate 14.

Fig. 3. Transverse Section of Pump.

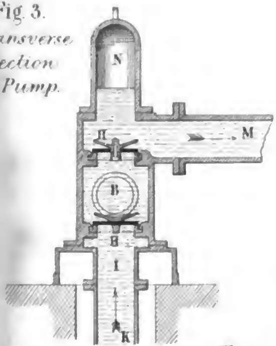
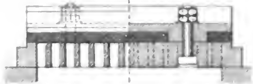


Fig. 5. Transverse Section of Pump Valve.

Fig. 6. Longitudinal Section of Pump Valve.



Scale 1/15th

Fig. 4. Transverse Section of Steam Cylinder.

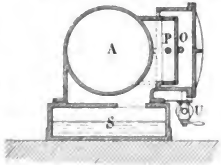
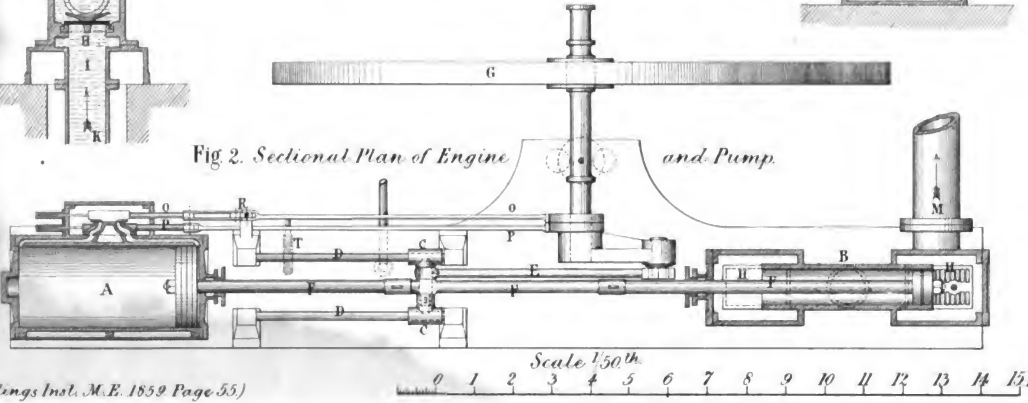


Fig. 2. Sectional Plan of Engine and Pump.



Scale 1/50th

(Proceedings Inst. M.E. 1859 Page 55.)

Fig. 7. *Elevation of Expansion Gear and Valves.*

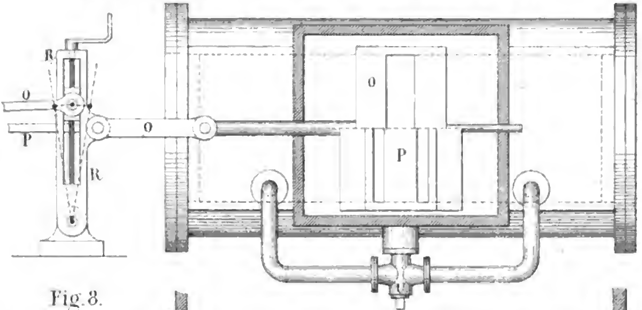
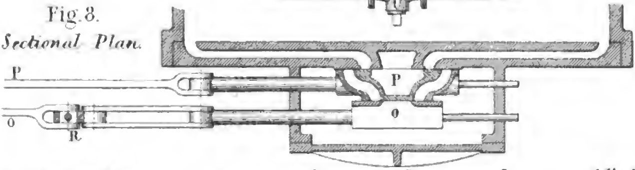
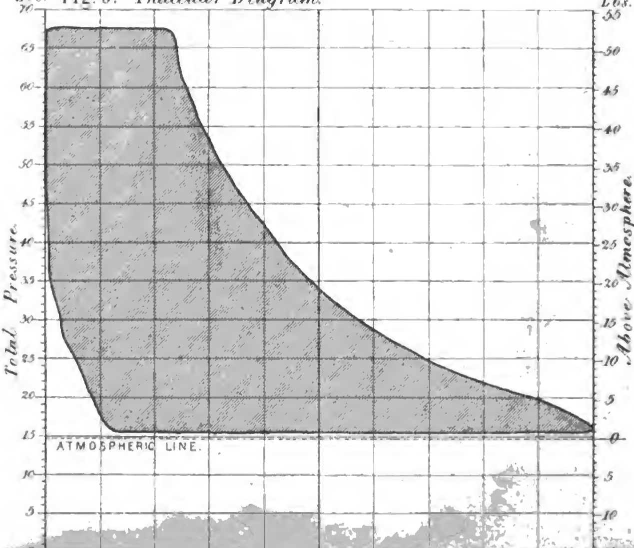


Fig. 8.
Sectional Plan.



Scale 1/20th. Ins. 12 6 0 1 2 3 4 *Feet.*

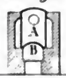
Lbs. Fig. 9. *Indicator Diagram.* Lbs.



(Proceedings Inst. M. E. 1859. Page 55.)

Fig. 1. *Neilson's Original Hot Blast Arrangement, Clyde Iron Works, Glasgow. 1829.*

Fig. 2. *Transverse Section of Fig. 1.*



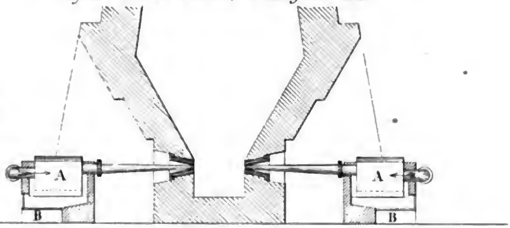


Fig. 3. *Neilson's improved form of Heating Vessel. Clyde. 1829.*

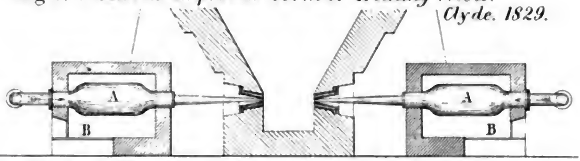


Fig. 4. *Neilson's Arrangement for Heating in Flues. Clyde. 1830.*

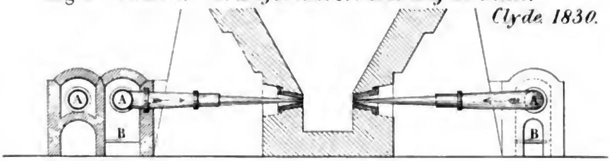
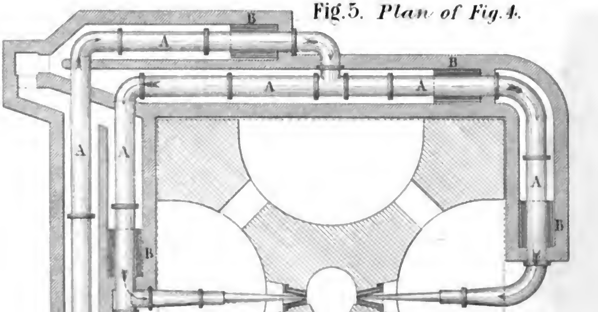


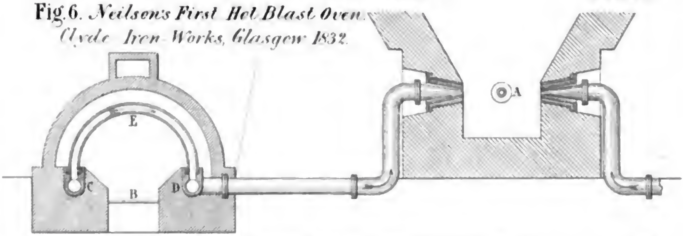
Fig. 5. *Plan of Fig. 4.*



Scale 1/150th.

10 5 0 10 20 30 *Feet.*

Fig. 6. *Neilson's First Hot Blast Oven.*
Clyde Iron Works, Glasgow 1832.



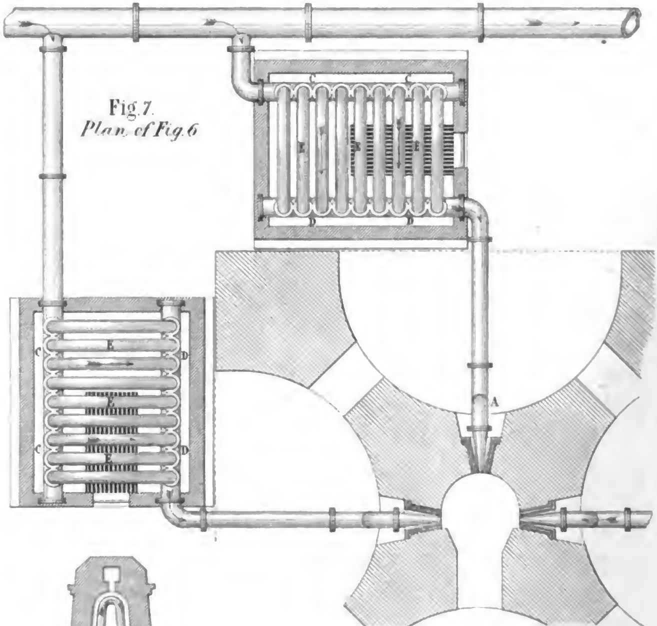
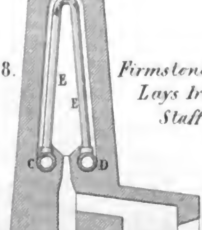


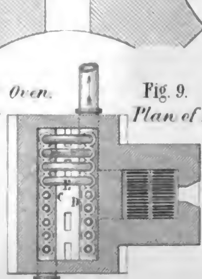
Fig. 7.
Plan of Fig. 6.

Fig. 8.



Firmstone's First Hot Blast Oven.
Lays Iron Works, Dudley.
Staffordshire 1833.

Fig. 9.
Plan of Fig. 8.



Scale 1/100th.
0 5 10 15 Feet

Fig. 10. *Continuous-Pipe Oven. Dowlais. 1836.*

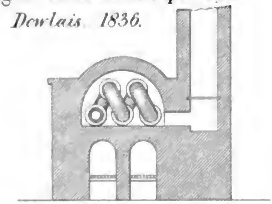


Fig. 12. *Box-Foot Oven. Ystalyfera and North Staffordshire.*

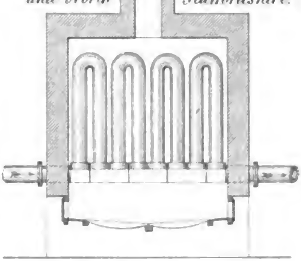


Fig. 11. *Longitudinal Section of Fig. 10.*

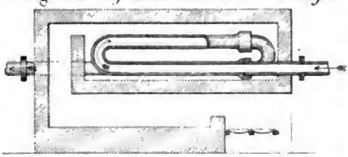


Fig. 13. *Plan of Fig. 12.*

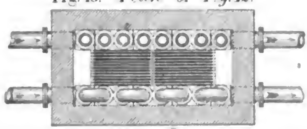


Fig. 14. *Spiral-Pipe Oven. Ebbw Vale.*

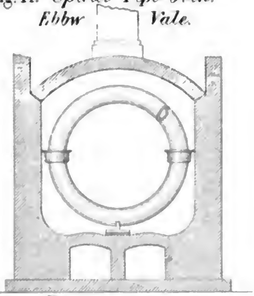


Fig. 16. *Double-Pipe Oven. Codnor Park. 1836.*

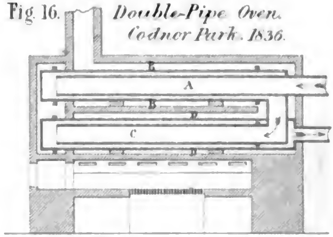


Fig. 15. *Plan of Fig. 14.*

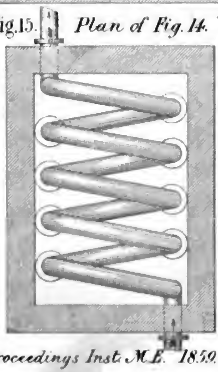


Fig. 17. *Transverse Section of Fig. 16.*

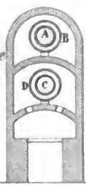
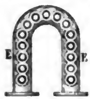
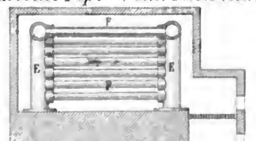


Fig. 19. *Transverse Section of Fig. 18.*



Horizontal-Pipe Oven. Monkland.

Fig. 18.



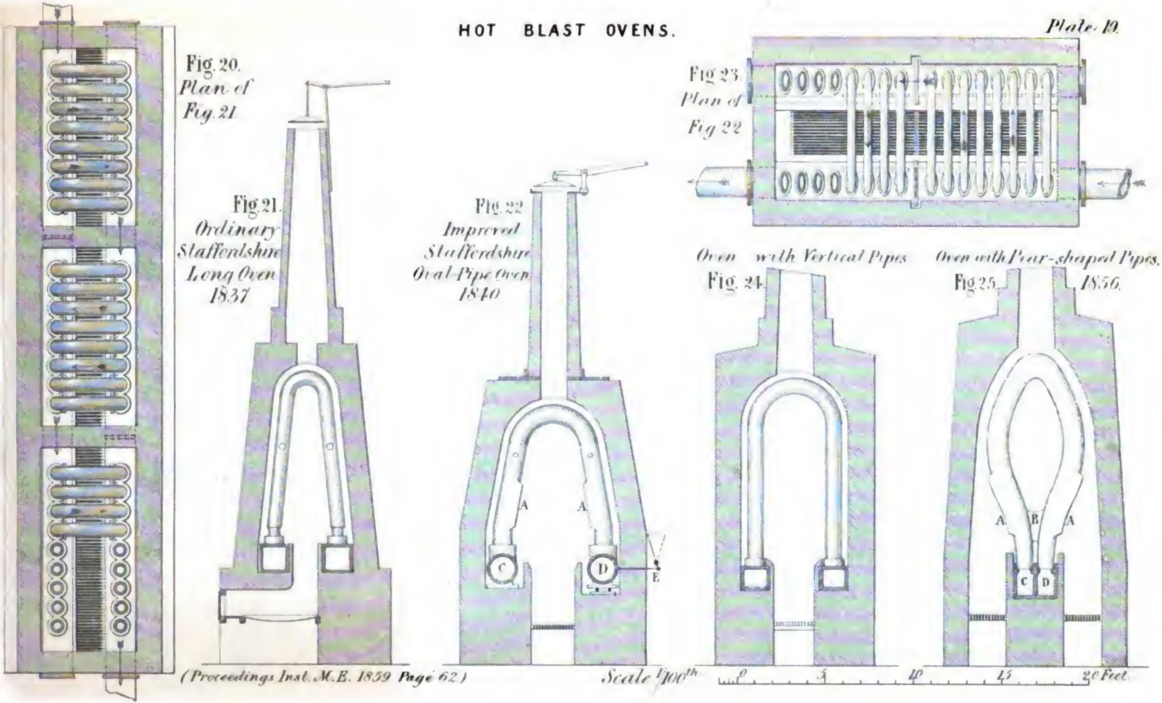
Scale 1/100th.

0 5 10 15 Feet.

(Proceedings Inst. M.E. 1859. Page 62.)

HOT BLAST OVENS.

Plate 19.



(Proceedings Inst. M.E. 1859 Page 62.)

Fig. 26. *Bilston 1851* *Baldwin's First Round Oven.*

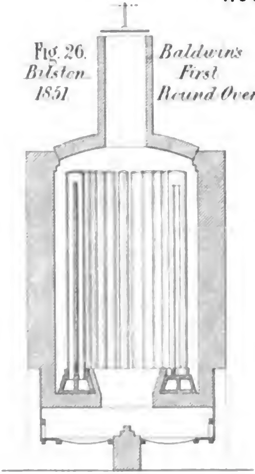


Fig. 28. *Improved Round Oven with Core* *Forest of Dean 1857*

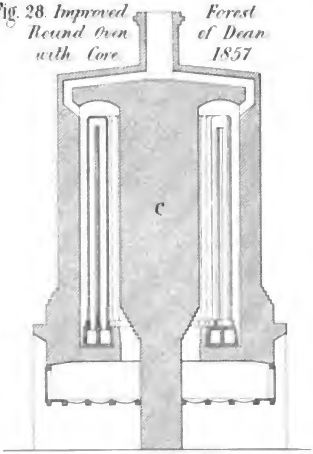


Fig. 27. *Plan of Fig. 26.*

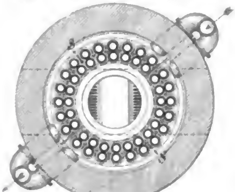
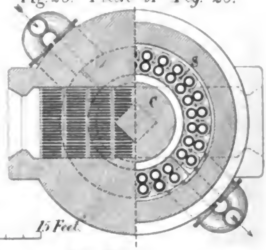


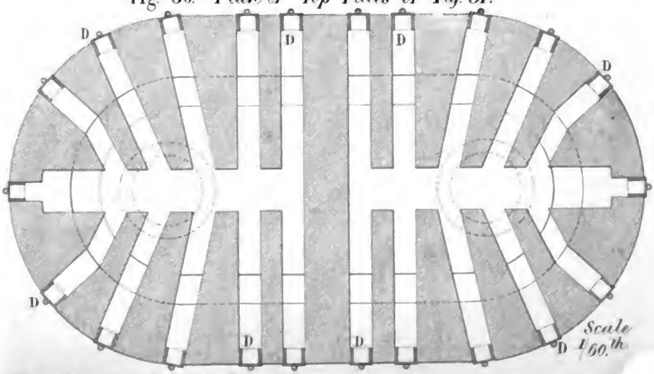
Fig. 29. *Plan of Fig. 28.*



Scale 1/100th.

0 5 10 15 Feet.

Fig. 30. *Plan of Top Flues of Fig. 31.*



Scale 1/60th.

Fig. 31. *Improved Oval Oven with Core Parkfield Iron Works, Wolverhampton 1858.*

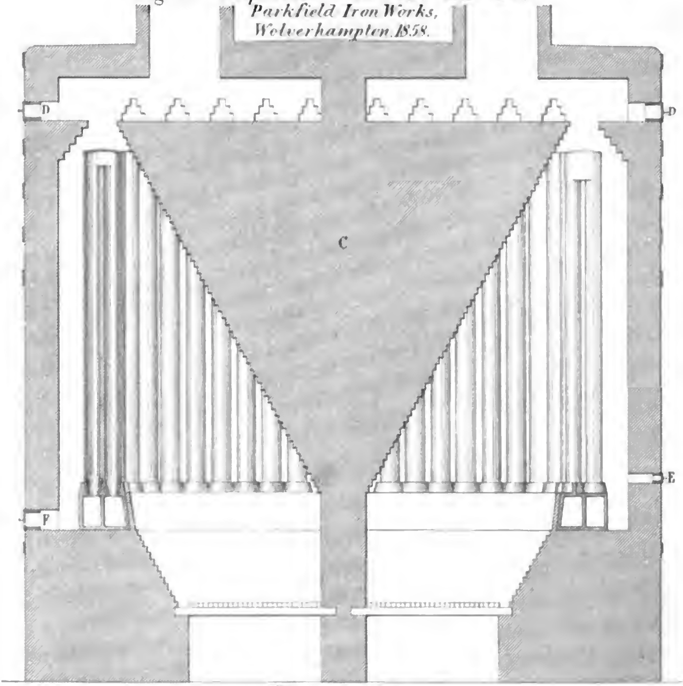
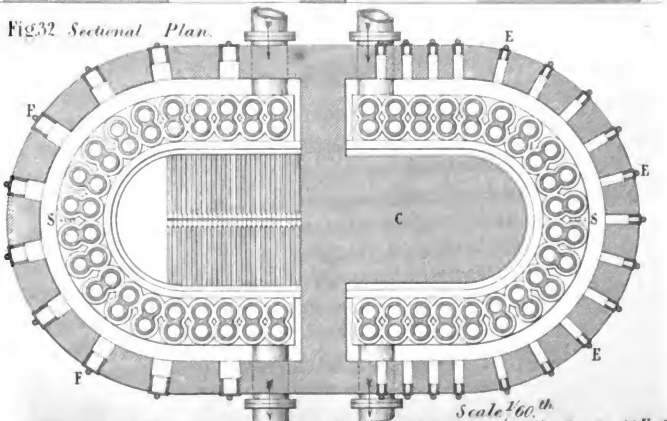


Fig.32 *Sectional Plan.*



Sections of Heating Pipes. *Scale 1/8th*

Fig. 33. *Neilson's First Oven.* *(Fig. 6.)*

Fig. 34. *Staffordshire Long Oven.* *(Fig. 21.)*

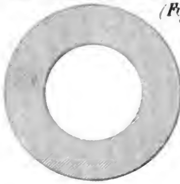


Fig. 35. *Staffordshire Oval-Pipe Oven.* *(Fig. 22.)*

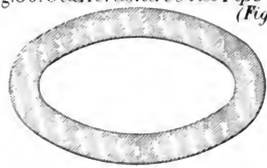


Fig. 36. *Flat-Pipe Oven.* *(Fig. 24.)*

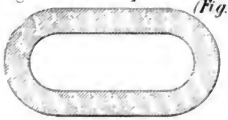
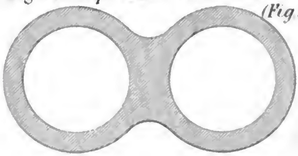


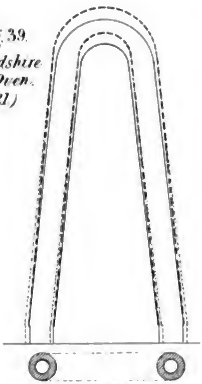
Fig. 37. *First Round Oven.* *(Fig. 26.)*

Fig. 38. *Improved Oval Oven.* *(Fig. 31.)*



Diagrams illustrating Expansion of Pipes.

Fig. 39. *Staffordshire Long Oven.* *(Fig. 21.)*



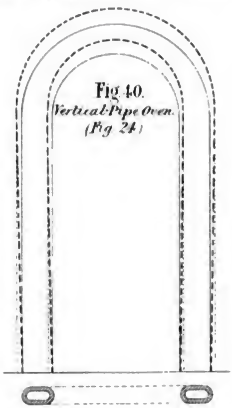


Fig. 40. *Vertical-Pipe Oven.* *(Fig. 24.)*

Fig. 41. *Round and Oval Ovens.* *(Figs. 26 and 31.)*

(Proceedings Inst. M. E. 1859. Page 62.)

Fig. 1. *Transverse Section of Vessel with Governor.*

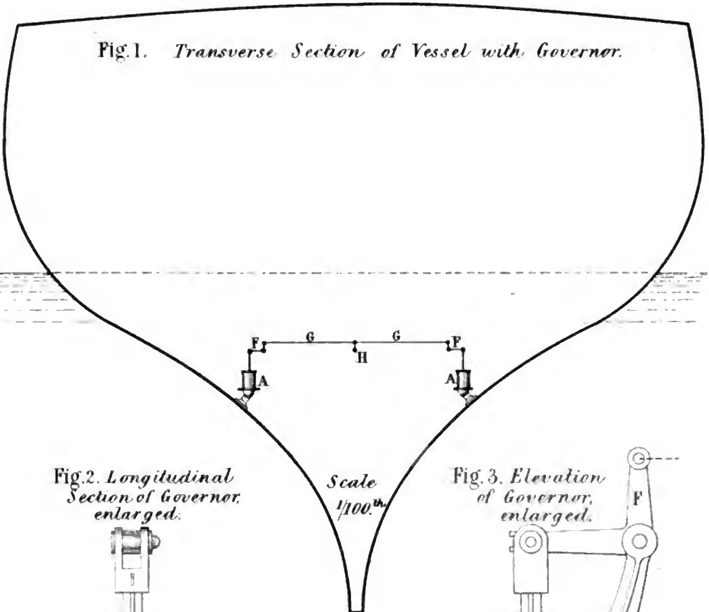


Fig. 2. *Longitudinal Section of Governor, enlarged.*

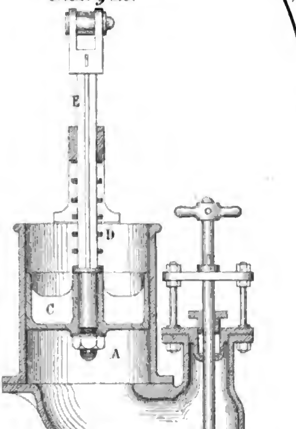
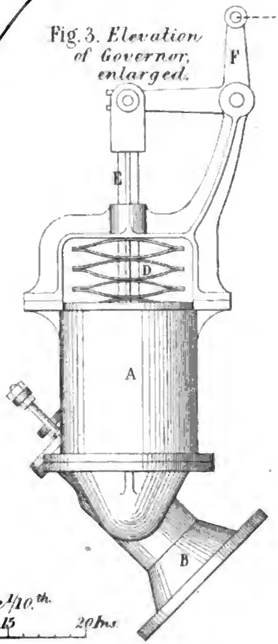


Fig. 3. *Elevation of Governor, enlarged.*



Scale 1/10th.

0 5 10 15 20 Ins.

Plate 24.

Whitworth's Measuring Machine
for measuring to the one millionth of an inch
by End or Contact measurement

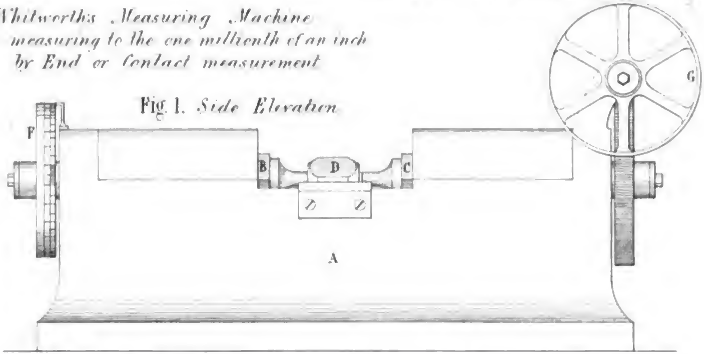


Fig. 1. *Side Elevation.*

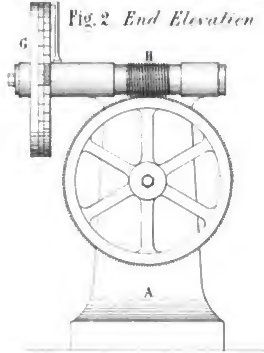


Fig. 2. *End Elevation.*

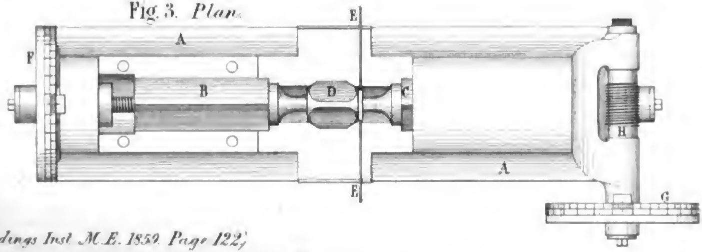


Fig. 3. *Plan.*

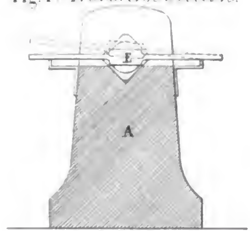


Fig. 4. *Transverse Section.*

(Proceedings Inst. M.E. 1859. Page 122.)

Plate 25.

Whitworth's Microscope Instrument for comparing Line measures.

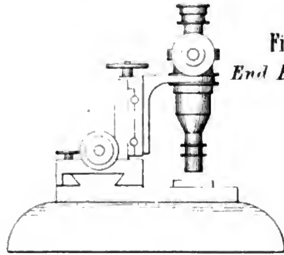
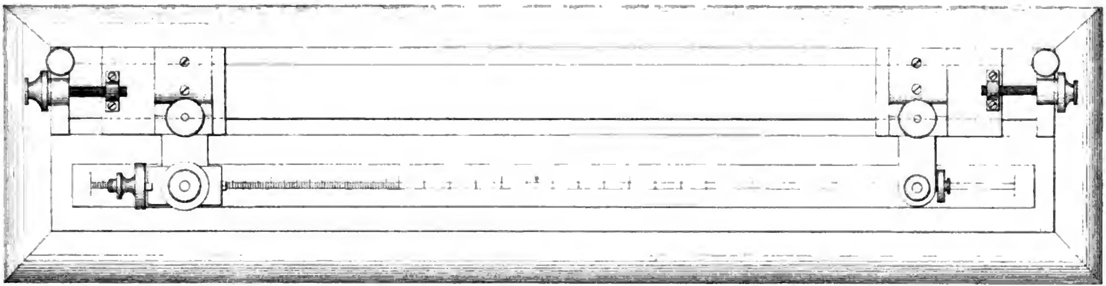


Fig. 6. *End Elevation.*

Fig. 5. *Plan.*



(Proceedings Inst. M. E. 1859 Page 126)

Fig. 7. *Comparative Decimal Scales.*

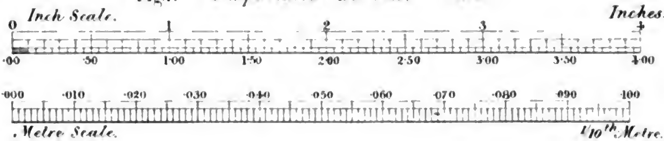


Fig. 8. *Standard Plugs for Decimal Wire Gauges.*

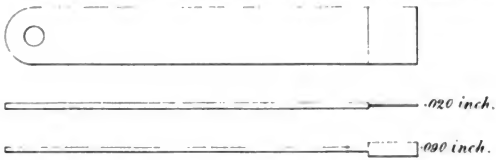


Fig. 9. *Cylindrical Standard Gauges (smallest size).*

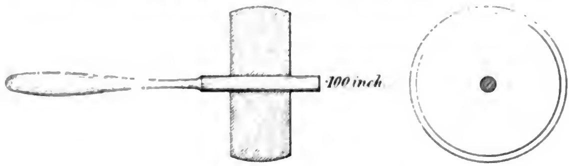


Fig. 10. *Standard Bar for End Measure.*

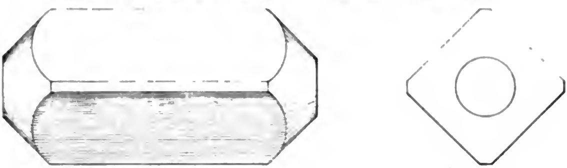


Fig. 11.

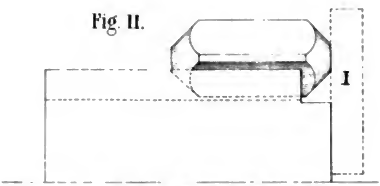
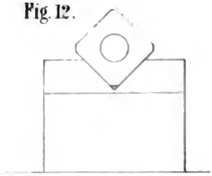
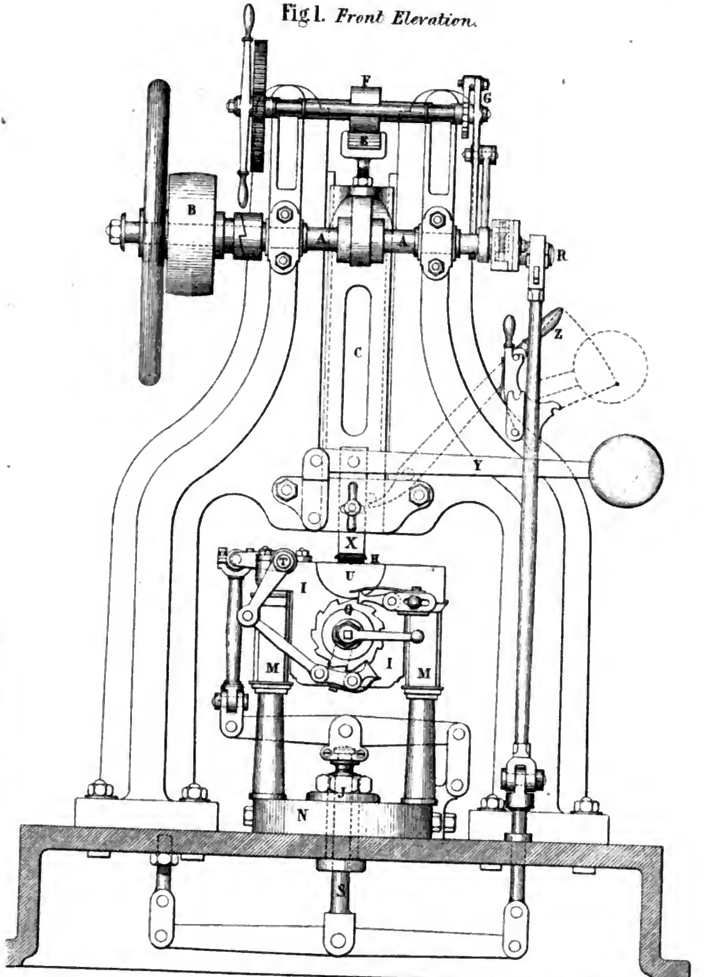


Fig. 12.



(Proceedings Inst. M.E. 1859. Page 113.)

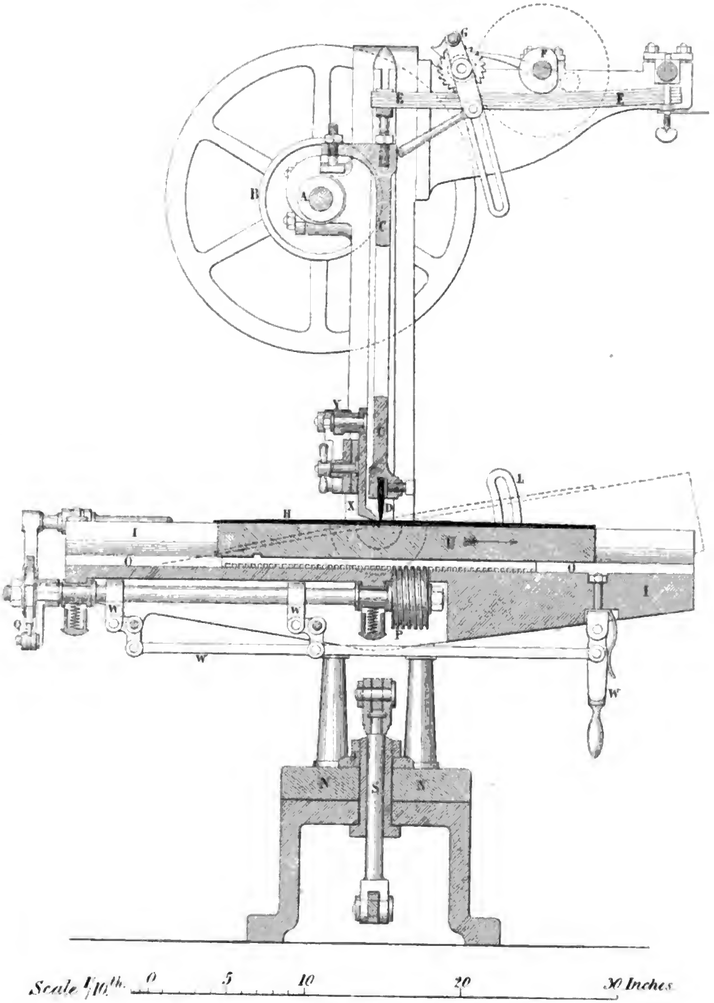
Fig 1. *Front Elevation.*



Scale 1/10th 0 5 10 20 30 *Inches.*

(Proceedings Inst. M.E. 1859. Page 134)

Fig. 2. *Vertical Section.*



(Proceedings Inst. M.E. 1859. Page 134)

Fig. 3. *Plan.*

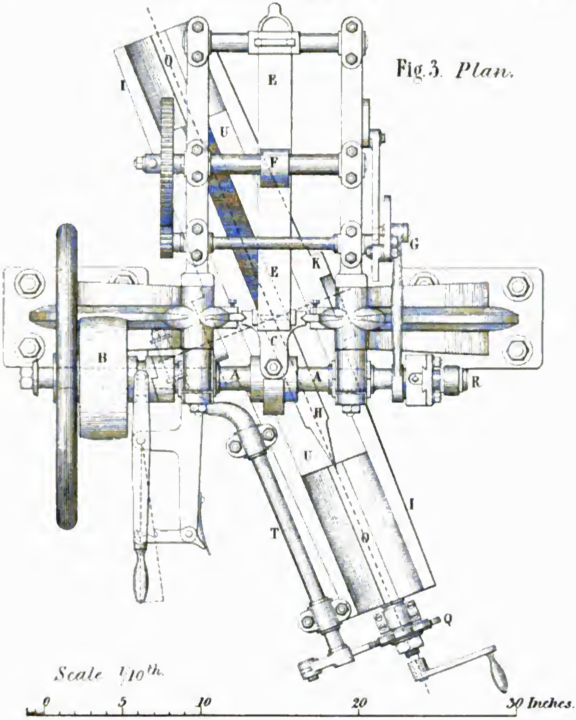
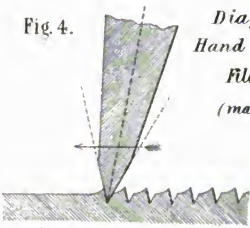


Fig. 4.



Diagrams of Hand and Machine File Cutting. (magnified)

Fig. 5.

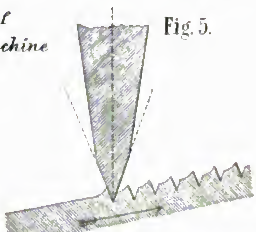
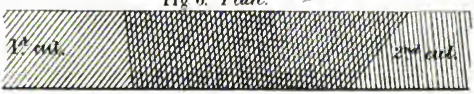


Fig. 6. *Plan.*



FILE-CUTTING MACHINE. Plate 30.

Fig. 7. *Side Elevation of File Bed.*

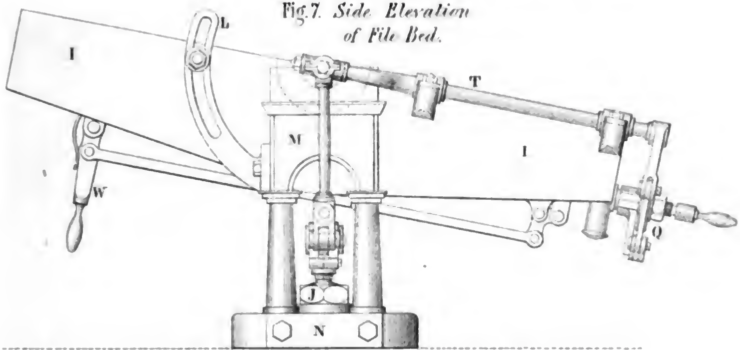


Fig. 8. *Transverse Section of File Bed.*

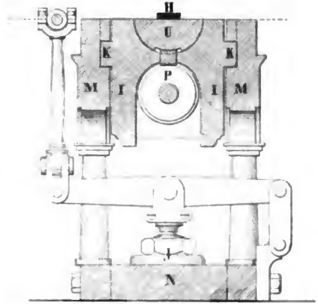
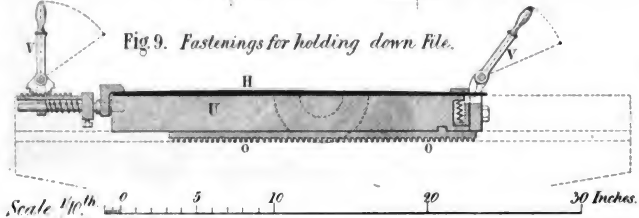


Fig. 9. *Fastenings for holding down File.*



Chisel and Leveller, enlarged.

Fig. 10. *Vertical Section.*

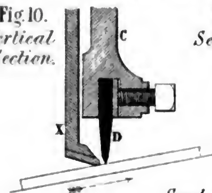
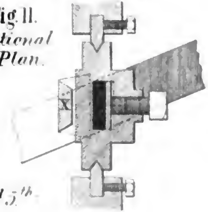


Fig. 11. *Sectional Plan.*



Scale 1/5th

(Proceedings Inst. M.E. 1859. Page 134.)

Fig. 1. *Cylindrical Boiler with Two Flues.*

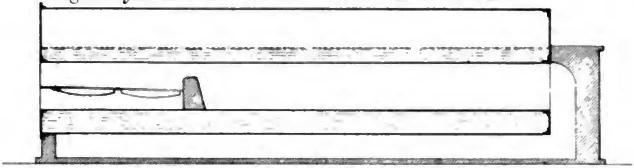


Fig. 3. *Cylindrical Boiler with Five Flues.*

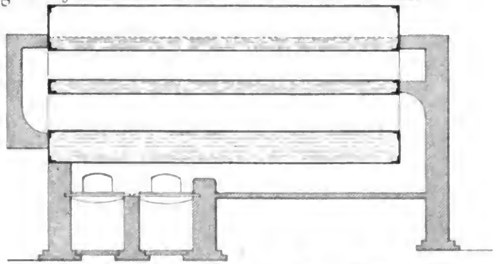
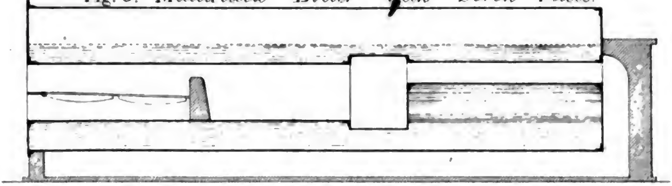


Fig. 5. *Multiflued Boiler with Seven Flues.*



Transverse Section of Fig. 1.

Fig. 2.

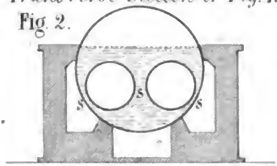
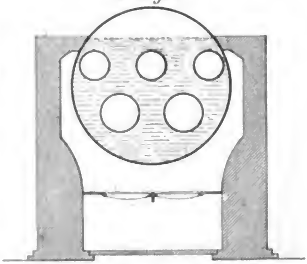
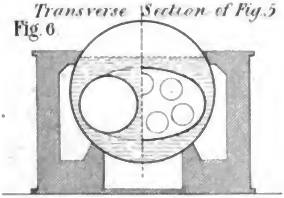


Fig. 4. *Transverse Section of Fig. 3.*



Transverse Section of Fig. 5

Fig. 6



Scale $^1/_{100}{}^{th}$

Fig. 7. *Galloway Boiler.*

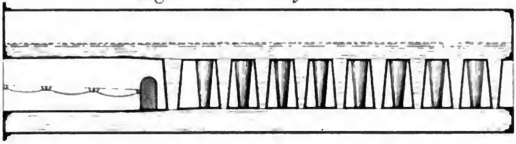
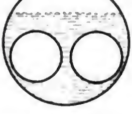


Fig. 8.



Transverse Sections of Fig. 7.

Fig. 9.

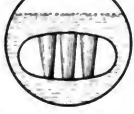
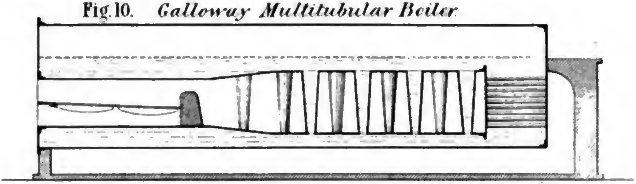


Fig. 10. *Galloway Multitubular Boiler.*



Transverse Sections of Fig. 10.

Fig. 11.

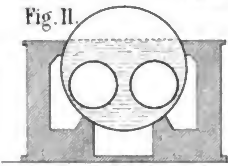


Fig. 12.

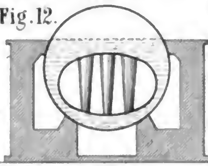


Fig. 13.

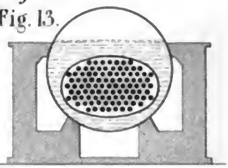
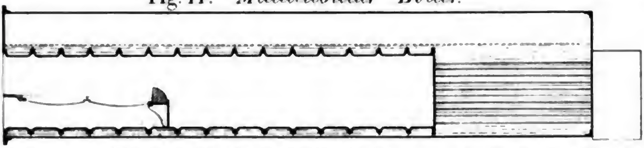
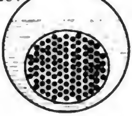


Fig. 14. *Multitubular Boiler.*



Transverse Section of Fig 14.
Fig. 15.



End Elevation of Fig. 14.
Fig. 16.

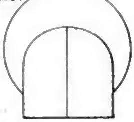
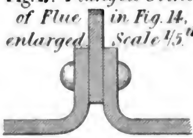


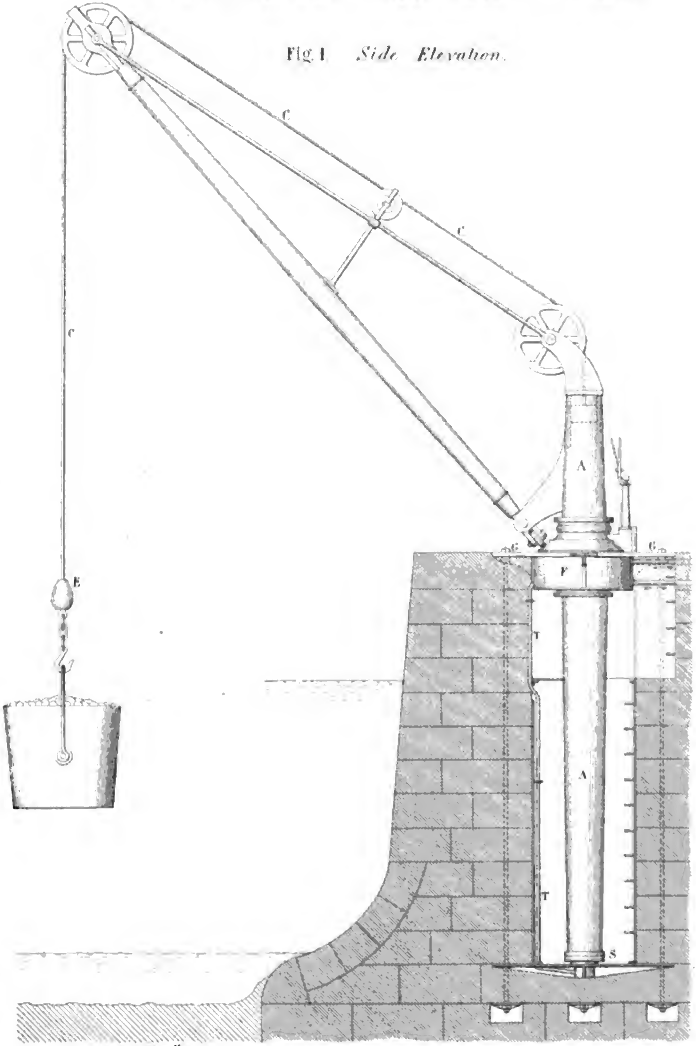
Fig. 17. *Flanged Joint of Flue in Fig. 14, enlarged. Scale 1/5th.*



Scale 1/100th.
(Proceedings Inst. M.E. 1859. Page 147.)

DIRECT-ACTING STEAM CRANE. Plate 33.

Fig. 1 *Side Elevation.*



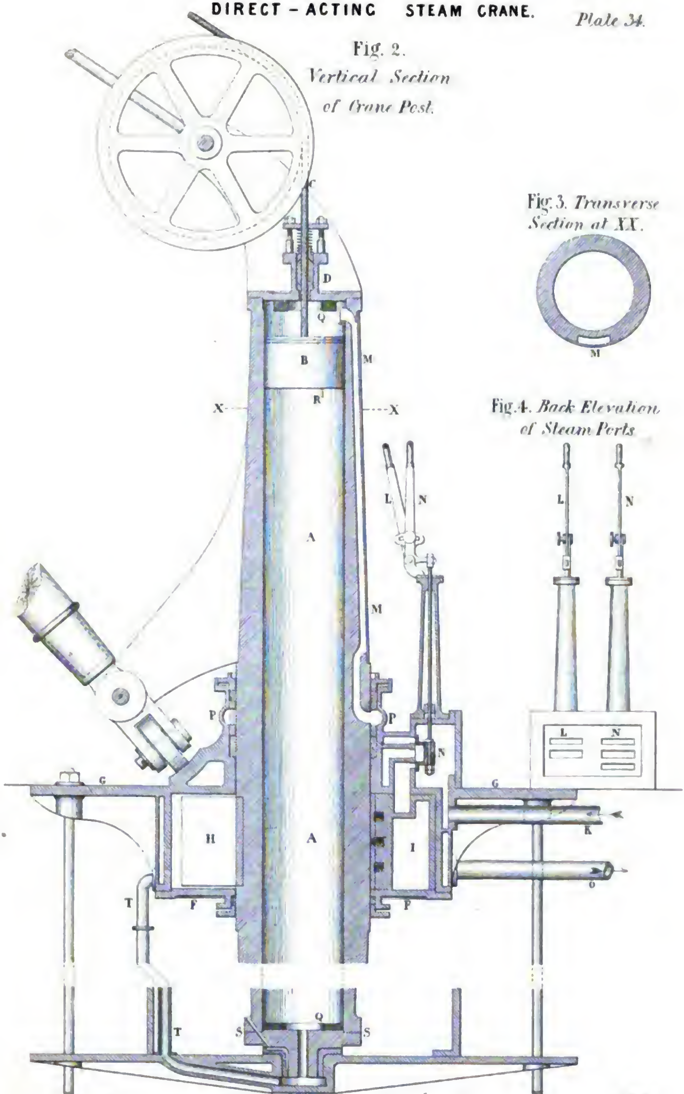
(Proceedings Inst. M.E. 1859. Page 168.)

DIRECT-ACTING STEAM CRANE.

Fig. 2. *Vertical Section of Crane Post.*

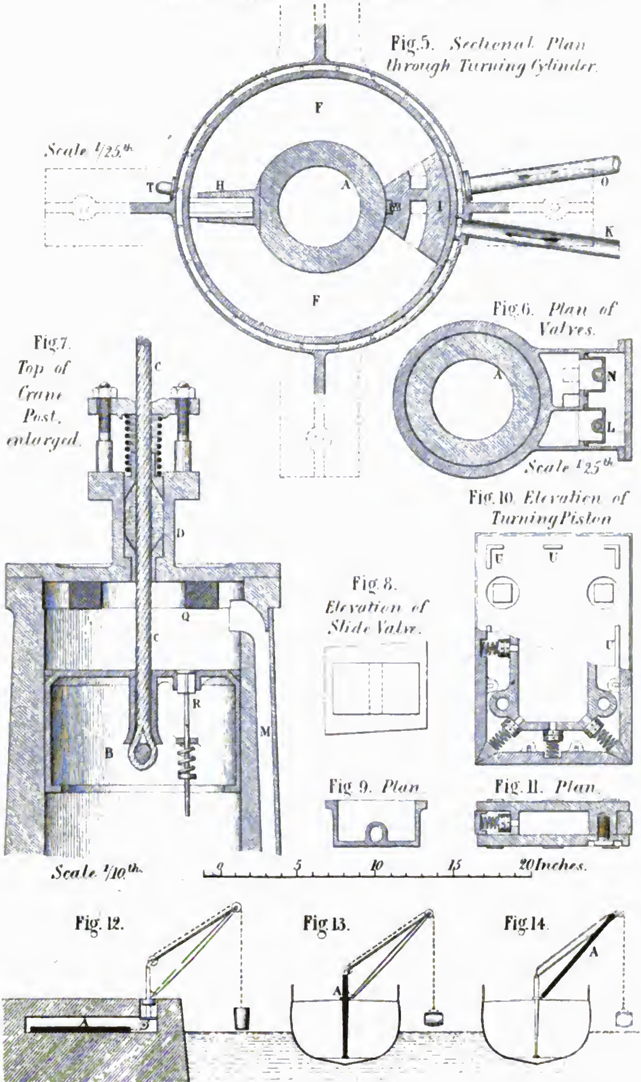
Fig. 3. *Transverse Section at XX.*

Fig. 4. *Back Elevation of Steam Ports.*



Scale $\frac{1}{25}$*th.* 0 1 2 3 4 5 *Feet.*

(Proceedings Inst. M.E. 1859. Page 168.)



(Proceedings Inst. M.E. 1859. Page 168.)

Fig. 1. *Vertical Section.*

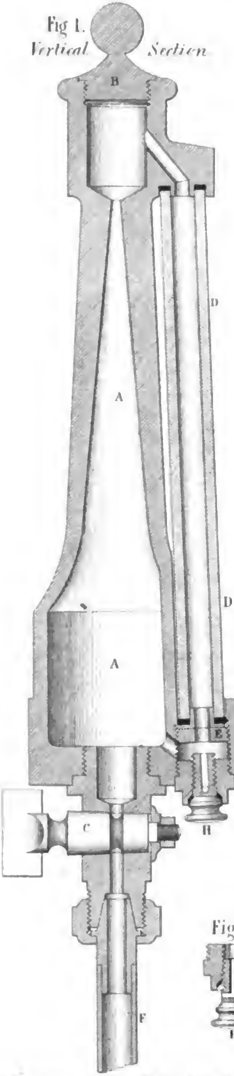


Fig. 3. *Plan.*

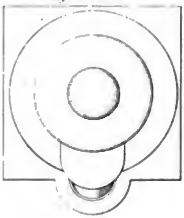


Fig. 4 *Sectional Plan.*

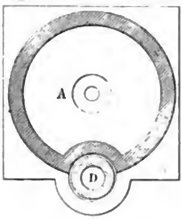


Fig. 5. *Transverse Section of Cock.*

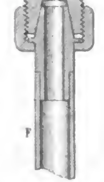
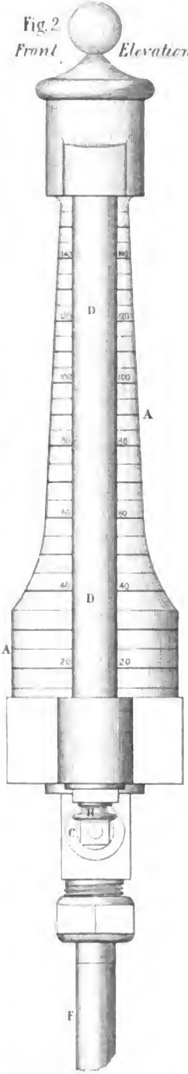


Fig. 6.

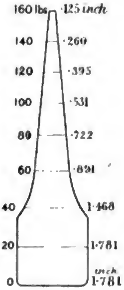
Fig. 2 *Front Elevation.*



(Proceedings Inst. M. E. 1859. Page 179.)

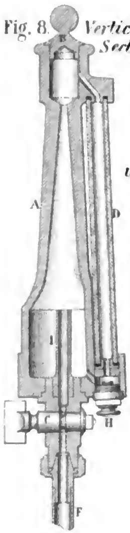
Scale ½ full size.

Fig. 7.



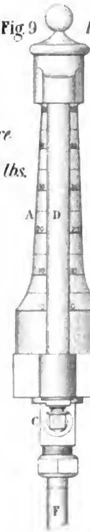
Scale 1/4th.

Fig. 8. *Vertical Section.*



Pressure Gauge up to 50 lbs.

Fig. 9. *Front Elevation.*



Scale 1/4th.

Fig. 10.

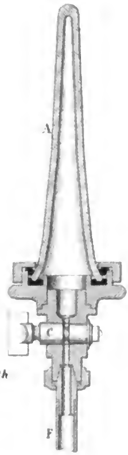


Fig. 11.

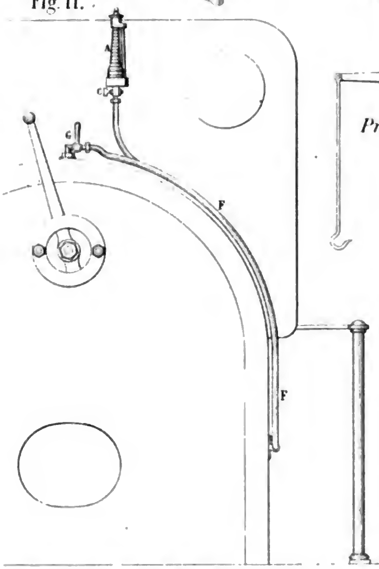
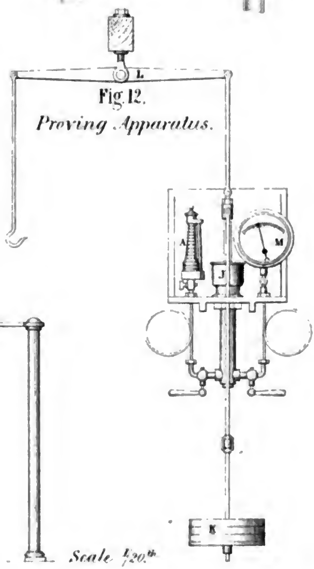


Fig. 12. *Proving Apparatus.*



Scale 1/20th.

SAFETY VALVE.

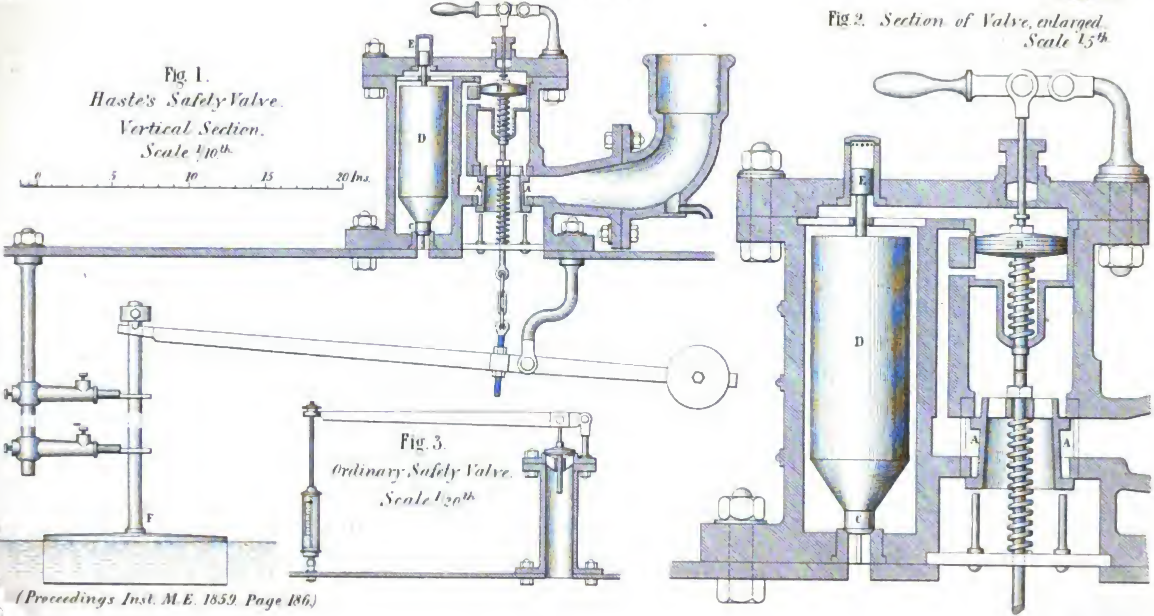


Fig. 1.
Haste's Safety Valve.
Vertical Section.
Scale 1/10th.

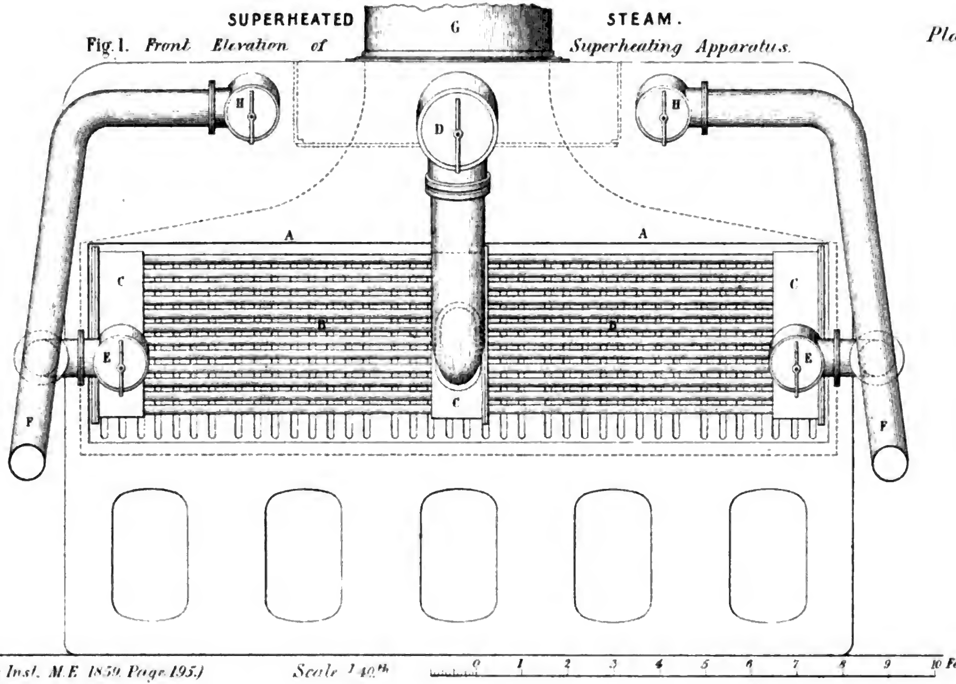
Fig. 2. Section of Valve, enlarged.
Scale 1/5th.

Fig. 3.
Ordinary Safety Valve.
Scale 1/20th.

(Proceedings Inst. M.E. 1859. Page 186.)

SUPERHEATED STEAM.

Fig. 1. *Front Elevation of Superheating Apparatus.*



Scale 1/40th

SUPERHEATED STEAM.

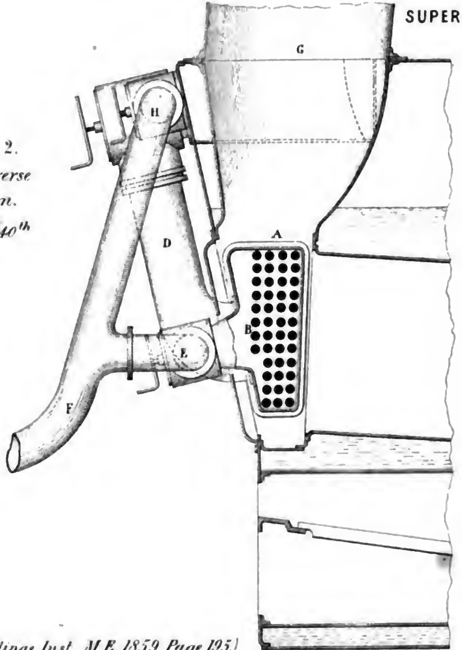


Fig. 2.
Transverse Section.
Scale 1/40th

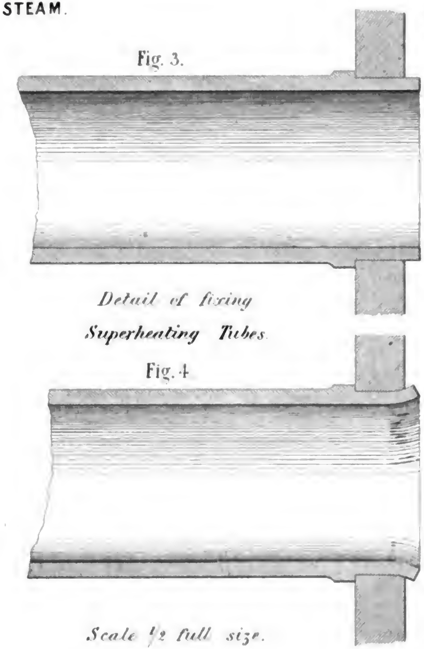


Fig. 3.

Detail of fixing Superheating Tubes.

Fig. 4

Scale 1/2 full size.

(Proceedings Inst. M.E. 1859. Page 195.)

Fig. 1. *Side Elevation.*

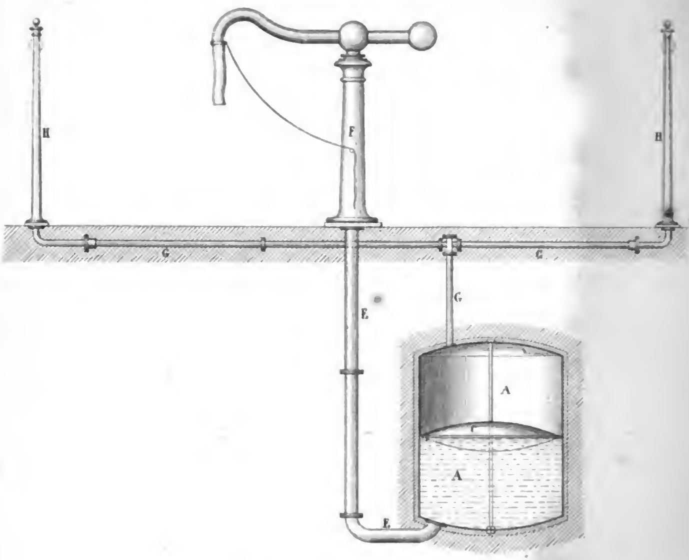
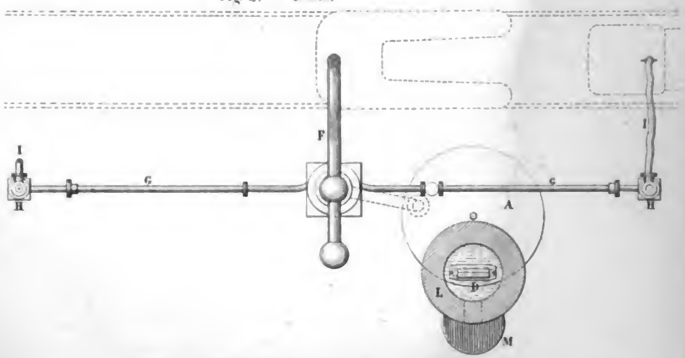


Fig. 2. *Plan.*



Scale 1/100th. 0 5 10 15 20 *Feet.*

(Proceedings Inst. M.E. 1859. Page 211.)

Fig. 3.
Scale 1/300th.

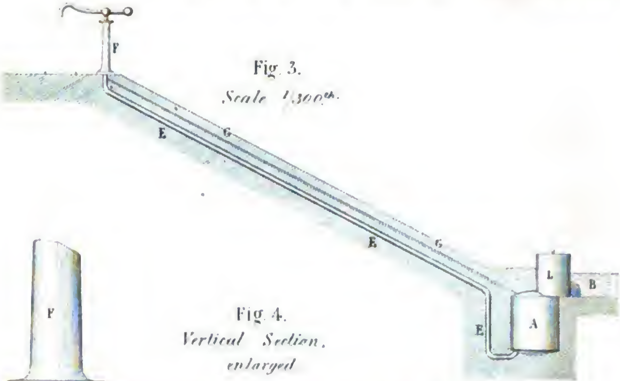
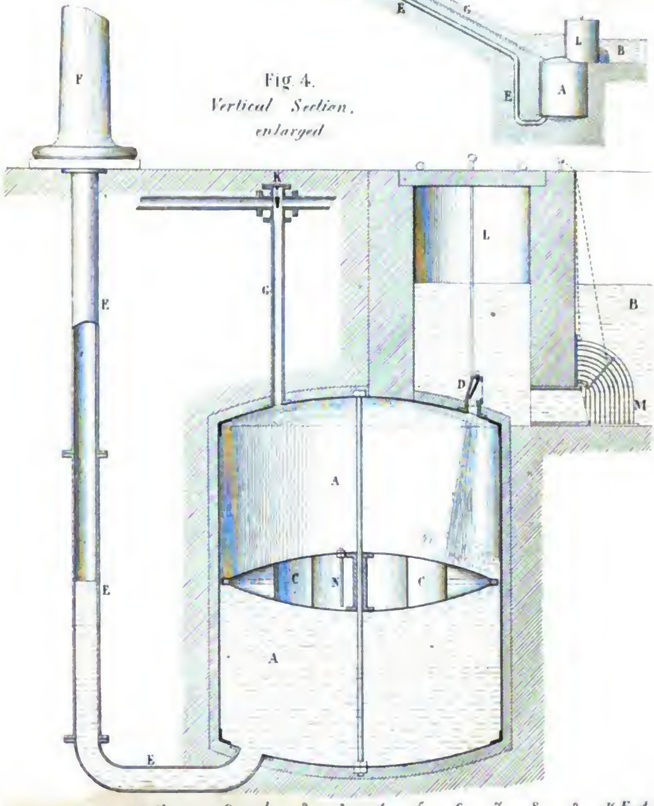


Fig. 4.
Vertical Section, enlarged



Scale 1/50th
(Proceedings Inst. M.E. 1859. Page 211.)

Fig 1. *Double-Flued Boiler without Stays.*

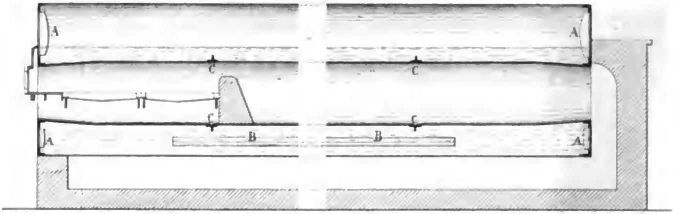


Fig. 2. *Transverse Section; on One wall.*

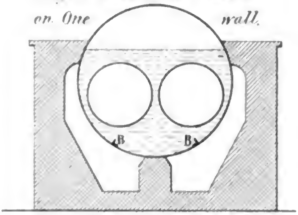
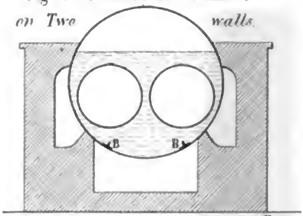


Fig. 3. *Transverse Section; on Two walls.*



Scale 1/70th. 0 5 10 15 *Feet.*

Fig 4. *Joint of Flue enlarged. Scale 1/5th.*

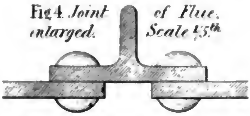
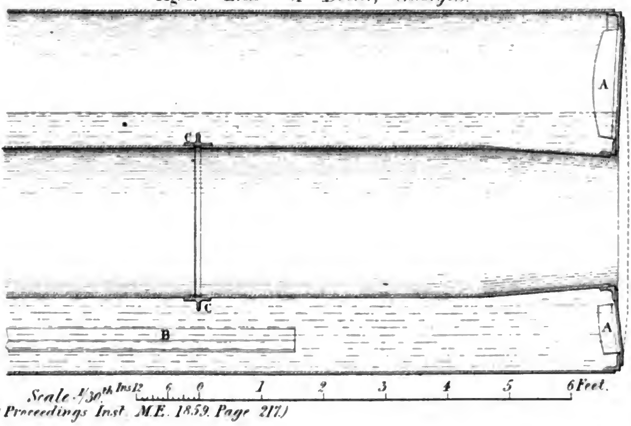


Fig 5. *End of Boiler, enlarged.*



Scale 1/30th Ins 12 6 0 1 2 3 4 5 6 *Feet.*

(Proceedings Inst. M.E. 1859. Page 217.)

Fig 6. *Ordinary Double-Flued Boiler with Stays.*

Fig 7. *Sectional Plan.*

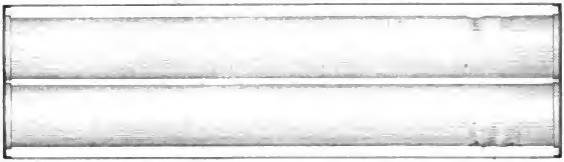


Fig 8. *Transverse Section.*

Fig 9. *Gusset Stay. Scale 1/20th.*

Scale 1/70th. 0 1 2 3 4 5 6 7 8 9 10 Feet

Fig 10. *Plain Cylindrical Boiler.*

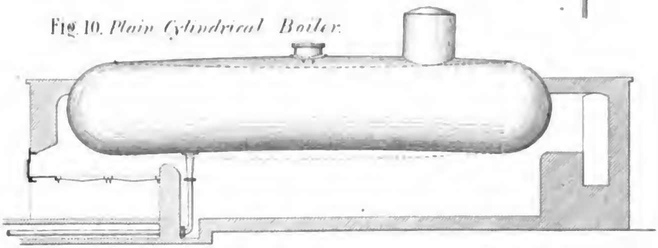


Fig 11. *Multitubular Boiler. with Arch Tubes.*

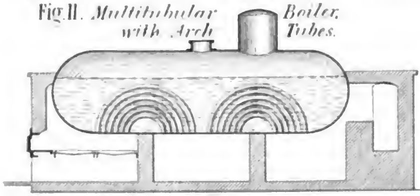
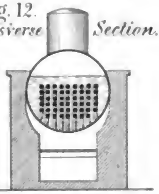


Fig. 12. *Transverse Section.*



Scale 1/140th. 0 10 20 30 Feet

(Proceedings Inst. M.E. 1859. Page 217)

Fig. 1. *Side Elevation of Locomotive with Steam Break.*

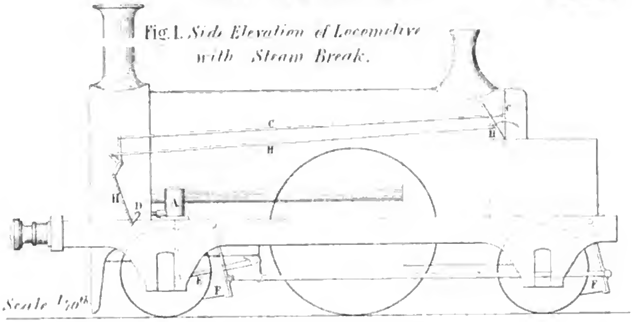


Fig. 2. *Detail of Steam Break, enlarged*

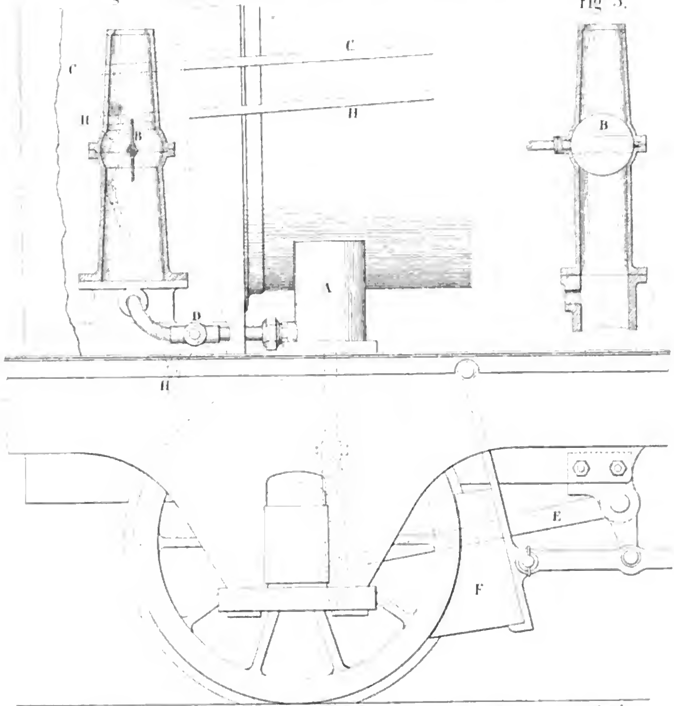


Fig. 3.

Scale 1/20th 0 10 20 30 40 50 *Inches.*

STEAM CRANE.

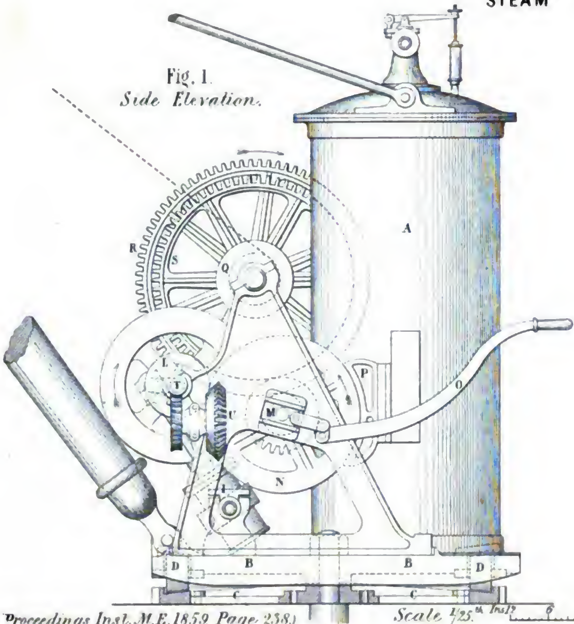


Fig. 1.
Side Elevation.

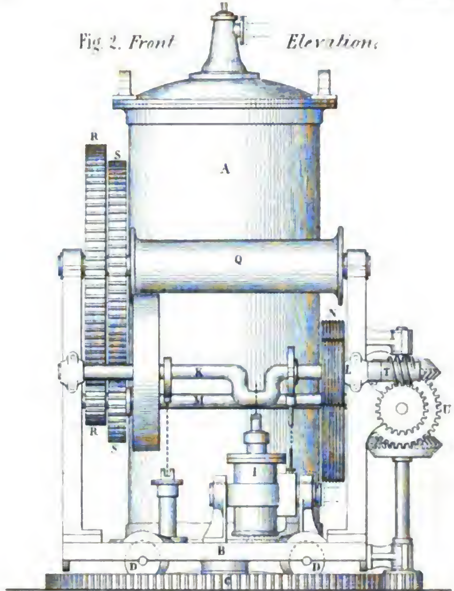
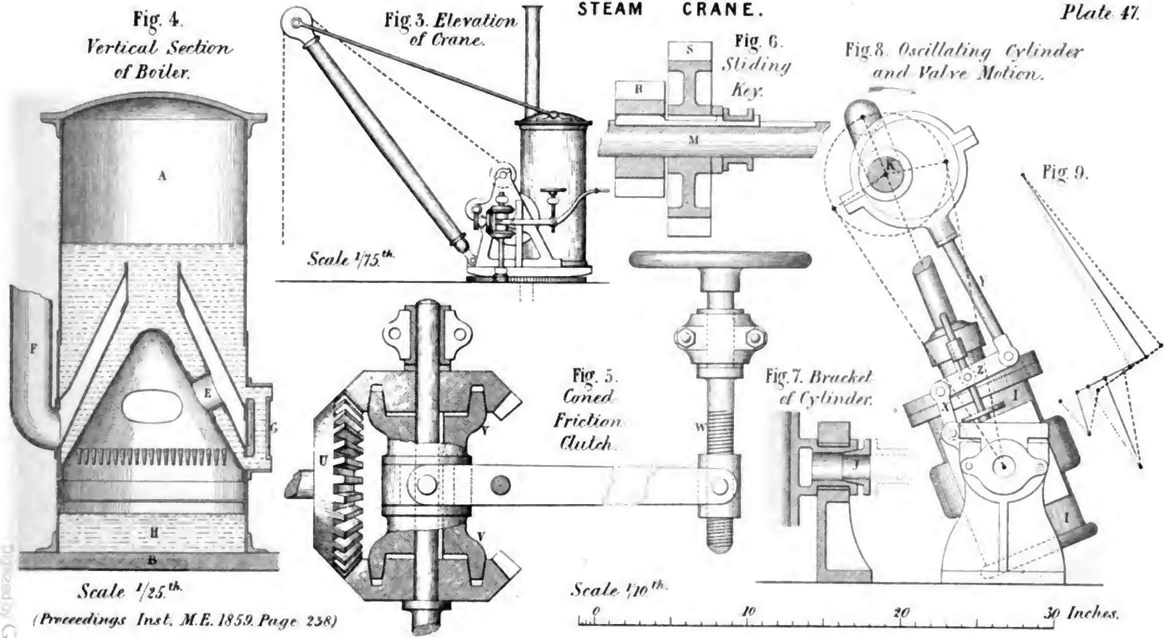


Fig. 2. Front Elevation.

Scale 1/25th Ins. 12 6 0 1 2 3 4 5 6 Feet.

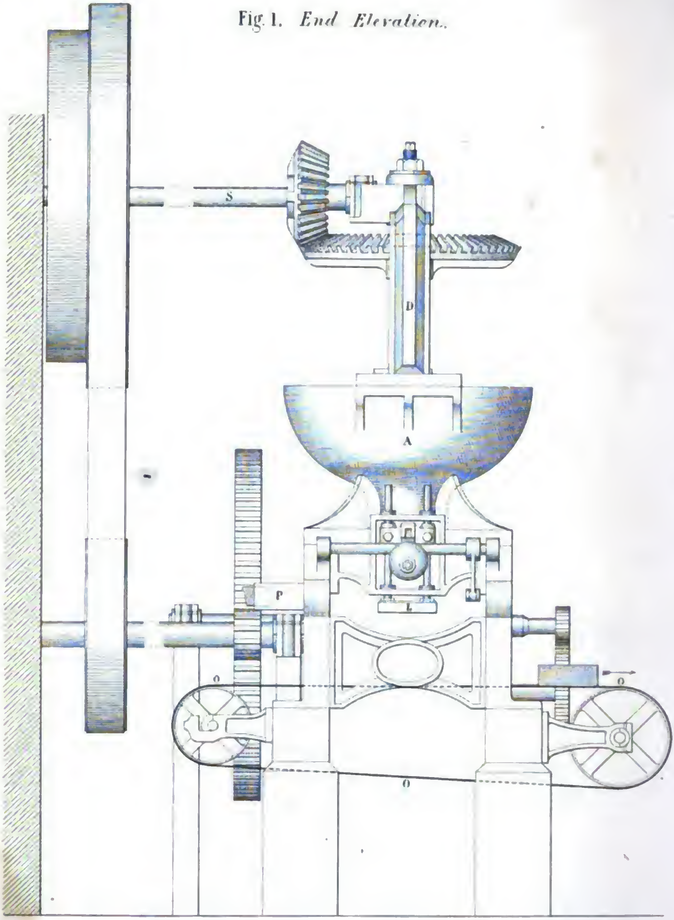
STEAM CRANE.

Plate 47.



(Proceedings Inst. M.E. 1859. Page 238)

Fig. 1. *End Elevation.*



Scale 1/24th Ins. 12 6 0 1 2 3 4 5 Feet.

(Proceedings Inst. M.E. 1859 Page 249.)

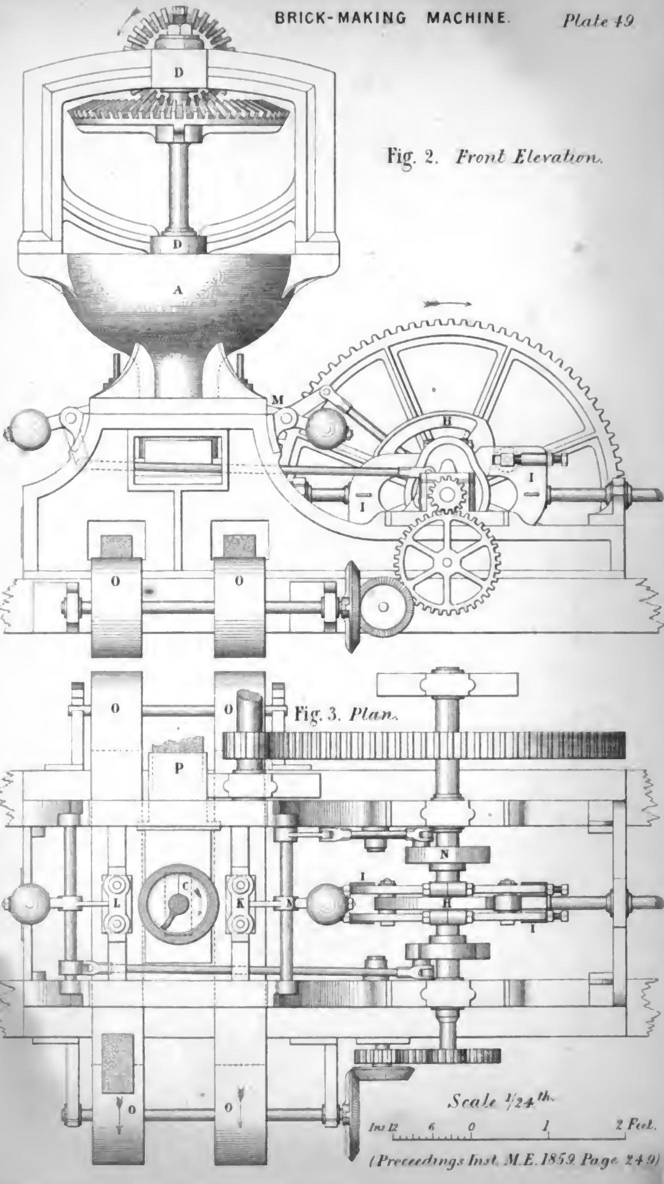


Fig. 2. *Front Elevation.*

Fig. 3. *Plan.*

Scale 1/24th.

BRICK-MAKING MACHINE.

Plate 50.

Fig. 4. *Transverse Section.*

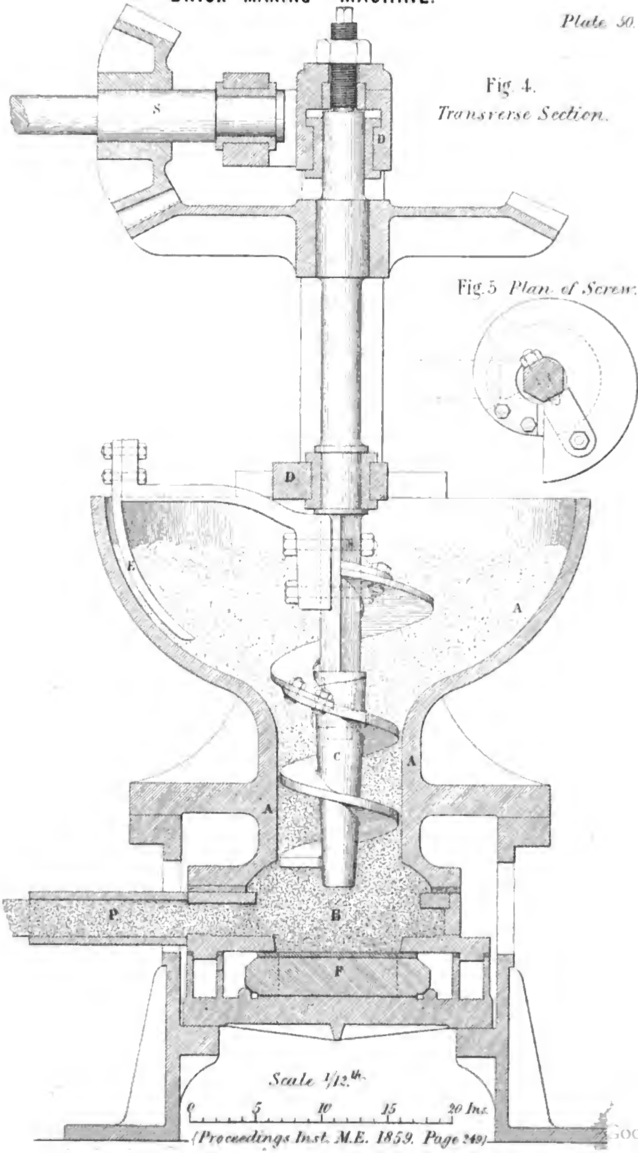


Fig. 5 *Plan of Screw.*

BRICK-MAKING MACHINE.

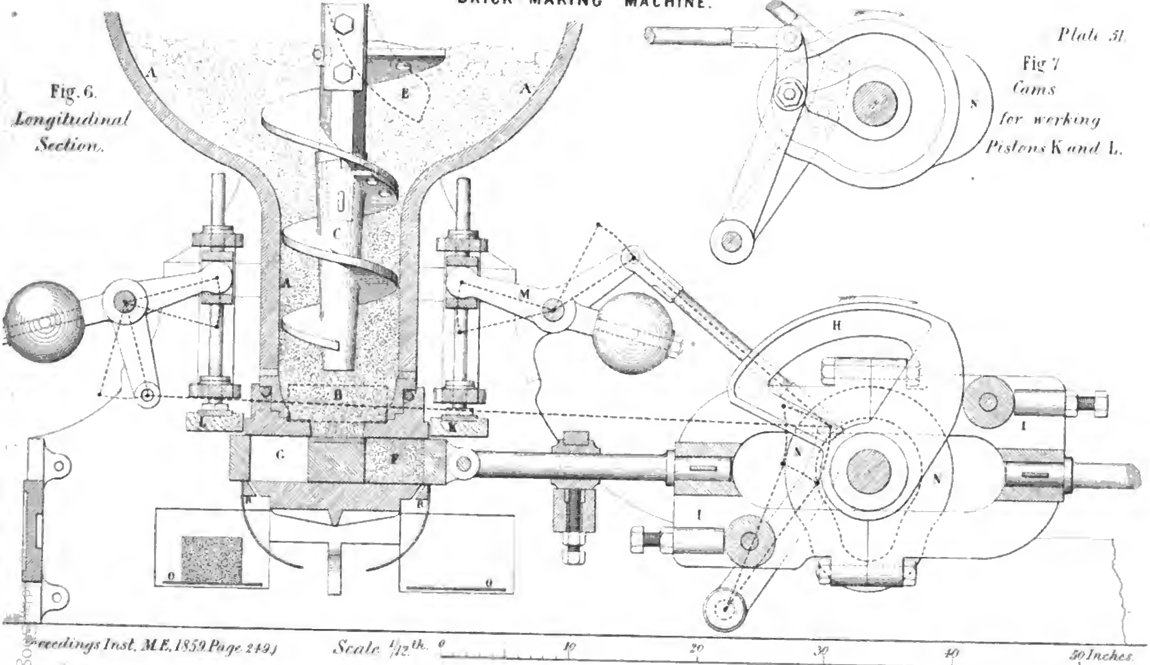


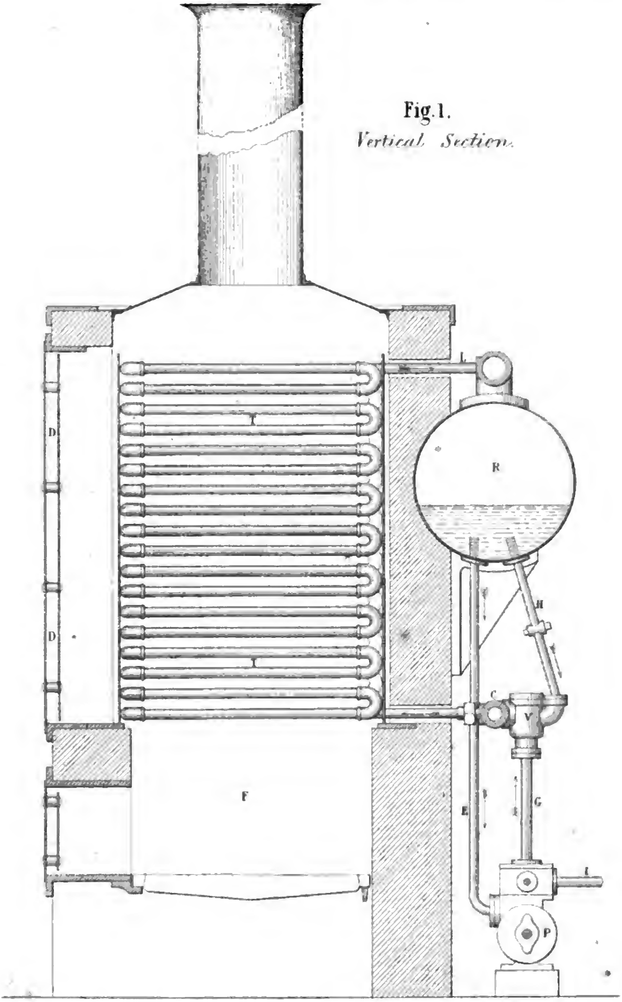
Fig. 6. Longitudinal Section.

Fig 7 Cams for working Pistons K and L.

Scale 1/12th.

Fig.1.

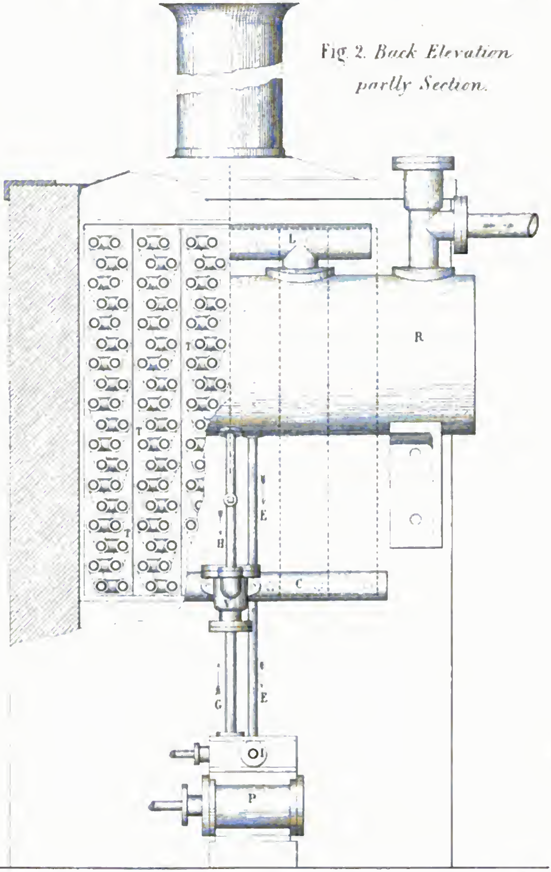
Vertical Section.



Scale 1/20th. Ins. 12 6 0 1 2 3 4 Feet.

(Proceedings Inst. M.E. 1859. Page 264.)

Fig. 2. *Back Elevation partly Section.*



Scale 1/20th. Ins. 12 6 0 1 2 3 4 Feet

Fig. 3.

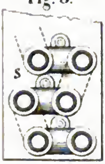
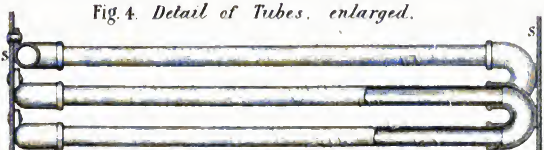


Fig. 4. *Detail of Tubes, enlarged.*



Scale 1/10th.

(Proceedings Inst. M.E. 1859 Page 264.)

Plate 54.

HIGH PRESSURE STEAM BOILER.

Marine Boiler

Fig. 5. *Vertical Section.*

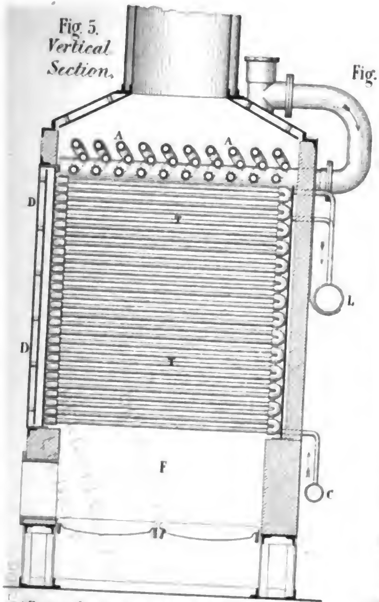


Fig. 6. *Transverse Section and Back Elevation.*

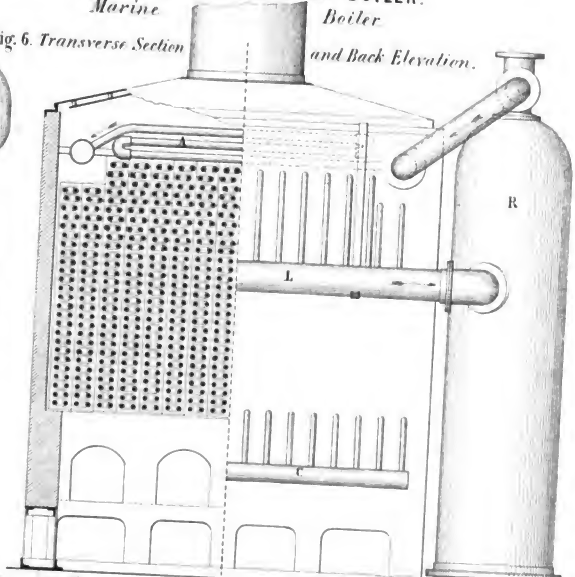
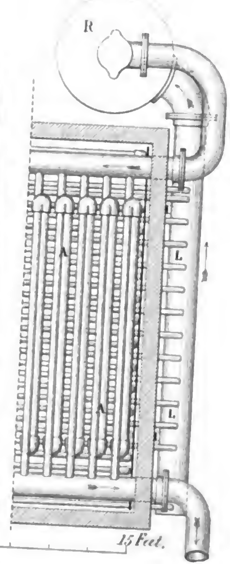


Fig. 7. *Plan.*



Scale 1/50th 0 5 10 15 *Feet.*

(Proceedings Inst. M. E. 1859. Page 264.)